S. I. A.

REPORT

OF THE

FORTIETH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

LIVERPOOL IN SEPTEMBER 1870.

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THE ASSOCIATION.

OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are,—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

ADMISSION OF MEMBERS AND ASSOCIATES.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions, shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

COMPOSITIONS, SUBSCRIPTIONS, AND PRIVILEGES.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

Annual Subscribers shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

Associates for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.

2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.

3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]

4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]

5. Associates for the year, subject to the payment of One Pound.

6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz. :—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two-thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than* 100 *copies remain*, at one-third of the Publication Price. Application to be made (by letter) to Messrs. Taylor & Francis, Red Lion Court, Fleet St., London.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

MEETINGS.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee at the previous Meeting; and the Arrangements for it shall be entrusted to the Officers of the Association.

GENERAL COMMITTEE.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

Class A. Permanent Members.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association.*

The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.

CLASS B. TEMPORARY MEMBERS.

1. Presidents for the time being of any Scientific Societies publishing Transactions or, in his absence a delegate representing him. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

SECTIONAL COMMITTEES.

The General Committee shall appoint, at each Meeting, Committees, consisting severally of the Members most conversant with the several branches of Science, to advise together for the advancement thereof.

The Committees shall report what subjects of investigation they would particularly recommend to be prosecuted during the ensuing year, and brought under consideration at the next Meeting.

The Committees shall recommend Reports on the state and progress of particular Sciences, to be drawn up from time to time by competent persons, for the information of the Annual Meetings.

COMMITTEE OF RECOMMENDATIONS.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects, shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

LOCAL COMMITTEES.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

OFFICERS.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

COUNCIL.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

PAPERS AND COMMUNICATIONS.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

ACCOUNTS.

The Accounts of the Association shall be audited annually, by Auditors appointed by the Meeting.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c.	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S., F.G.S. J. C. Prichard, M.D., F.R.S.	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir D. T. Acland, Bart.	W. Snow Harris, Esq., F.R.S. Col. Hamilton Smith, F.L.S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq., F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres.R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.

The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. York, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.
SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c. Cambridge, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. G. B. Airy, Esq., M.A., D.C.L., F.R.S. The Rev. Professor Sedgwick, M.A., F.R.S.	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. Southampton, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L. Lord Ashburton, D.C.L. Viscount Palmerston, M.P. Right Hon. Charles Shaw Lefevre, M.P. Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S. The Lord Bishop of Oxford, F.R.S. Professor Owen, M.D., F.R.S. Professor Powell, F.R.S.	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford Oxford, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S. The Vice-Chancellor of the University Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S. Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The MARQUIS OF NORTHAMPTON, President of the Royal Society, &c. Swansea, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S. Sir H. T. DelaBeche, F.R.S., Pres. G.S. The Very Rev. the Dean of Llandaff, F.R.S. Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S. J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's	Matthew Moggridge, Esq. D. Nicol, M.D.
The REV. T. R. ROBINSON, D.D., M.R.I.A., F.R.A.S. Birmingham, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S. Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S. Charles Darwin, Esq., M.A., F.R.S., Sec. G.S. Professor Faraday, D.C.L., F.R.S. Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews Edinburgh, July 21, 1850.	Right Hon. the Lord Provost of Edinburgh The Earl of Cathcart, K.C.B., F.R.S.E. The Earl of Rosebery, K.T., D.C.L., F.R.S. Right Hon. David Boyle (Lord Justice-General), F.R.S.E. General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E. Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. Professor J. D. Forbes, F.R.S., Sec. R.S.E.	Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal Ipswich, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich Rev. Professor Sedgwick, M.A., F.R.S. Rev. Professor Henslow, M.A., F.L.S. Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L. F.R.S. The Earl of Rosse, M.R.I.A., Pres. R.S. Sir Henry T. DelaBeche, F.R.S. Rev. Edward Hincks, D.D., M.R.I.A. Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Philos. Society William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull. Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The EARL OF HARROWBY, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, M.D.
The DUKE OF ARGYLL, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The REV. HUMPHREY LLOYD, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, LL.D.
RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural-History Departments of the British Museum LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.

HIS ROYAL HIGHNESS THE PRINCE CONSORT .. ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen. Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen..	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.
The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. .. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C.D.C.L., Chancellor of the Univ. of Oxford .. The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford .. The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F.R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, M.D., F.L.S. H. J. S. Smith, Esq., M.A., F.C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. .... MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, M.A., Esq. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D.C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. .. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Reverend the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford .... BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Reverend the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. | F. Osler, Esq., F.R.S. J. T. Chance, Esq. | The Rev. Charles Evans, M.A.	William Mathews, Esq., jun., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. .... NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, M.D., F.R.S., F.L.S. John Russell Hinds, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. .... DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh. James D. Forbes, LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonards, University of St. Andrews	J. Henderson, Esq., jun. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.

JOSEPH DALTON HOOKER, M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk. Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge. Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge. Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. The Earl of Devon. The Right Hon. Sir Stafford H. Northcote, C.B., Bart., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. The Earl of Derby, LL.D., F.R.S. Sir Philip De M. Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.
PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.S. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K.G., D.C.L., F.R.S. The Right Hon. The Lord Provost of Edinburgh The Right Hon. John Inglis, LL.D., Lord Justice General of Scotland. Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K.C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D.C.L., F.R.S., F.G.S. Dr. Lyon Playfair, M.P., C.B., F.R.S. Professor Christison, M.D., D.C.L., Pres. R.S.E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.

Presidents and Secretaries of the Sections of the Association.

Date and Place.	Presidents.	Secretaries.

MATHEMATICAL AND PHYSICAL SCIENCES.

COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.

1832. Oxford	Davies Gilbert, D.C.L., F.R.S....	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.............	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S..........	Prof. Forbes, Prof. Lloyd.

SECTION A.—MATHEMATICS AND PHYSICS.

1835. Dublin	Rev. Dr. Robinson..................	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol	Rev. William Whewell, F.R.S....	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool ..	Sir D. Brewster, F.R.S.............	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle...	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S.	J. D. Chance, W. Snow Harris, Prof. Stevelly.
1840. Glasgow ...	Prof. Forbes, F.R.S.	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth...	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork	Prof. M'Culloch, M.R.I.A.	J. Nott, Prof. Stevelly.
1844. York	The Earl of Rosse, F.R.S..........	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge..	The Very Rev. the Dean of Ely .	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford	Rev. Prof. Powell, M.A., F.R.S. .	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S..........	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh..	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich......	Rev. W. Whewell, D.D., F.R.S., &c.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull	The Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool...	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow ...	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S. ...	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.

Date and Place.	Presidents.	Secretaries.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.
1859. Aberdeen ...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford	Rev. B. Price, M.A., F.R.S.......	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester.	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge..	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof Stevelly.
1863. Newcastle...	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee......	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof Swan.
1868. Norwich ...	Prof. J. Tyndall, LL.D., F.R.S...	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof. G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool ...	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof. W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford	John Dalton, D.C.L., F.R.S.......	James F. W. Johnston.
1833. Cambridge..	John Dalton, D.C.L., F.R.S.... ..	Prof. Miller.
1834. Edinburgh...	Dr. Hope..............................	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming................	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool...	Michael Faraday, F.R.S.	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle...	Rev. William Whewell, F.R.S....	Prof. Miller, R. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Golding Bird, M.D., Dr. J. B. Melson.
1840. Glasgow ...	Dr. Thomas Thomson, F.R.S. ...	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth...	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester.	John Dalton, D.C.L., F.R.S.......	Dr. L. Playfair, R. Hunt, J. Graham.
1843. Cork	Prof. Apjohn, M.R.I.A.	R. Hunt, Dr. Sweeny.
1844. York	Prof. T. Graham, F.R.S.	Dr. R. Playfair, E. Solly, T. H. Barker.
1845. Cambridge..	Rev. Prof. Cumming................	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.

Date and Place.	Presidents.	Secretaries.
1848. Swansea ...	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S..........	R. Hunt, G. Shaw.
1850. Edinburgh .	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich ...	Prof. Thomas Graham, F.R.S....	T. J. Pearsall, W. S. Ward.
1852. Belfast	Thomas Andrews, M.D., F.R.S. .	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool ...	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow ...	Dr. Lyon Playfair, C.B., F.R.S. .	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S.	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen ...	Dr. Lyon Playfair, C.B., F.R.S. .	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford	Prof. B. C. Brodie, F.R.S.	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester .	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge .	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle...	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S. ...	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee ...	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich ...	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S. ...	Prof. A. Crum Brown, M.D., Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool...	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, M.D., A. E. Fletcher, Dr. W. J. Russell.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge .	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh .	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

SECTION C.—GEOLOGY AND GEOGRAPHY.

1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography.* R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool...	Rev. Prof. Sedgwick, F.R.S.—*Geography.* G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography.* Captain H. M. Denham, R.N.
1838. Newcastle...	C. Lyell, F.R.S., V.P.G.S.—*Geography.* Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography.* Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography.* G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.

Date and Place.	Presidents.	Secretaries.
1840. Glasgow ...	Charles Lyell, F.R.S.—*Geography.* G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth..	H. T. De la Beche, F.R.S.	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge ..	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton	Leonard Horner, F.R.S.—*Geography.* G. B. Greenough, F.R.S.	Robert A. Austen, J. H. Norten, M.D., Prof. Oldham.—*Geography.* Dr. C. T. Beke.
1847. Oxford	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea ...	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh *	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Professor Nicol.

SECTION C (*continued*).—GEOLOGY.

1851. Ipswich ...	William Hopkins, M.A., F.R.S...	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast......	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull.........	Prof. Sedgwick, F.R.S.	Prof. Harkness, William Lawton.
1854. Liverpool ..	Prof. Edward Forbes, F.R.S. ...	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow ...	Sir R. I. Murchison, F.R.S.	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S.	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin......	The Lord Talbot de Malahide ...	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen...	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford......	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. Woodall.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S., &c.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.......	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle...	Prof. Warington, W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.

* At the Meeting of the General Committee held in Edinburgh, it was agreed "That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section," for Presidents and Secretaries of which see page xxxii.

Date and Place.	Presidents.	Secretaries.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee......	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich ...	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool...	Sir Philip de M. Grey-Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford	Rev. P. B. Duncan, F.G.S.	Rev. Prof. J. S. Henslow.
1833. Cambridge*	Rev. W. L. P. Garnons, F.L.S....	C. C. Babington, D. Don.
1834. Edinburgh	Prof. Graham........................	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin	Dr. Allman............................	J. Curtis, Dr. Litton.
1836. Bristol	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool..	W. S. MacLeay	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle...	Sir W. Jardine, Bart...............	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Brimingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow ...	Sir W. J. Hooker, LL.D	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth...	John Richardson, M.D., F.R.S..	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork	William Thompson, F.L.S.	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York.........	Very Rev. The Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S.	Dr. Lankester, T. V. Wollaston.
1846. Southampton	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford.......	H. E. Strickland, M.A., F.R.S....	Dr. Lankester, Dr. Melville, T. V. Wollaston.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see pp. xxxi, xxxii.]

1848. Swansea ...	L. W. Dillwyn, F.R.S.	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S............	Dr. Lankester, Dr. Russell.
1850. Edinburgh..	Prof. Goodsir, F.R.S. L. & E. ...	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich......	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.

* At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see p. xxxi.

Date and Place.	Presidents.	Secretaries.
1853. Hull	C. C. Babington, M.A., F.R.S....	Robert Harrison, Dr. E. Lankester.
1854. Liverpool ...	Prof. Balfour, M.D., F.R.S.......	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E. ...	William Keddie, Dr. Lankester.
1856. Cheltenham.	Thomas Bell, F.R.S., Pres.L.S....	Dr. J. Abercrombie, Prof. Buckman, Dr. Lankester.
1857. Dublin	Prof. W.H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds.........	C. C. Babington, M.A., F.R.S....	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen ...	Sir W. Jardine, Bart., F.R.S.E..	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford	Rev. Prof. Henslow, F.L.S.	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester..	Prof. C. C. Babington, F.R.S....	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge...	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle ...	Prof. Balfour, M.D., F.R.S.	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath	Dr. John E. Gray, F.R.S.	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S.	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY*.

1866. Nottingham.	Prof. Huxley, LL.D., F.R.S.—*Physiological Dep.* Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.* Alfred R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee	Prof. Sharpey, M.D., Sec. R.S.—*Dep. of Zool. and Bot.* George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S.—*Dep. of Physiology.* W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S.—*Dep. of Bot. and Zool.* C. Spence Bate, F.R.S.—*Dep. of Ethno.* E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, M.D., E. Ray Lankester, Professor Lawson, H. T. Stainton, Rev. H. B. Tristram.
1870. Liverpool ...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. Anat. and Physio.* Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.* J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEES OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge...	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh...	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E. (UNTIL 1847.)—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool ...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.

* At the Meeting of the General Committee at Birmingham, it was resolved:—"That the title of Section D be changed to Biology;" and "That for the word 'Subsection,' in the rules for conducting the business of the Sections, the word 'Department' be substituted."

Date and Place.	Presidents.	Secretaries.
1838. Newcastle ...	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S.	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D................	Dr. J. Brown, Prof. Couper, Prof. Reid.
1841. Plymouth...	P. M. Roget, M.D., Sec.R.S. ...	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester.	Edward Holme, M.D., F.L.S. ...	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D.	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.

SECTION E.—PHYSIOLOGY.

1845. Cambridge .	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton	Prof. Owen, M.D., F.R.S..........	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford* ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas, K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S. ...	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen ...	Prof. Sharpey, M.D., Sec.R.S. ...	Prof. Bennett, Prof. Redfern.
1860. Oxford	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester.	Dr. John Davy, F.R.S.L. & E....	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge .	C. E. Paget, M.D.	G. F. Helm, Dr. Edward Smith.
1863. Newcastle...	Prof. Rolleston, M.D., F.R.S. ...	Dr. D. Embleton, Dr. W. Turner.
1864. Bath	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birminghm†.	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xxviii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A.	Prof. Buckley.
1848. Swansea ...	....	G. Grant Francis.
1849. Birmingham	....	Dr. R. G. Latham.
1850. Glasgow ...	Vice-Admiral Sir A. Malcolm ...	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich ...	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull	R. G. Latham, M.D., F.R.S. ...	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool...	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow ...	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.

* By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of "Section D—Zoology and Botany, including Physiology" (see p. xxx). The Section being then vacant was assigned in 1851 to Geography.

† *Vide* note on preceding page.

Date and Place.	Presidents.	Secretaries.
1857. Dublin	Rev. Dr. J. Henthawn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen	Rear-Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Professor Geddes, Dr. Norton Shaw.
1860. Oxford	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lempriere, Dr. Norton Shaw.
1861. Manchester	John Crawfurd, F.R.S.	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge	Francis Galton, F.R.S.	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir R. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, C. R. Markham, T. Wright.

SECTION E (*continued*).—GEOGRAPHY.

1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.

STATISTICAL SCIENCE.

COMMITTEES OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS.

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Charles Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow	Rt. Hon. Lord Sandon, F.R.S., M.P.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth	Lieut.-Col. Sykes, F.R.S.	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester	G. W. Wood, M.P., F.L.S.	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P.	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. The Earl Fitzwilliam	J. Fletcher, W. Cooke Tayler, LL.D.
1846. Southampton	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.

Date and Place.	Presidents.	Secretaries.
1847. Oxford	Travers Twiss, D.C.L., F.R.S. ...	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea ...	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede
1849. Birmingham	Rt. Hon. Lord Lyttelton	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh ..	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich......	Sir John P. Boileau, Bart.	J. Fletcher, Prof. Hancock.
1852. Belfast	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, Jun.
1853. Hull	James Heywood, M.P., F.R.S....	Edward Cheshire, William Newmarch.
1854. Liverpool ...	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow	R. Monckton Milnes, M.P.	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P. ...	Rev. C. H. Bromby, E. Cheshire, Dr W. N. Hancock Newmarch, W. M Tartt.
1857. Dublin	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds.........	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen ...	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S.	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge..	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle ...	William Tite, M.P., F.R.S.	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath..........	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers...............	R. Birkin, Jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich ...	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	Edmund Macrory, Frederick Purdy, Charles T. D. Acland.
1870. Liverpool...	Prof. W. Stanley Jevons, M.A. ..	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S....	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool ...	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle ...	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robert Stephenson.	W. Carpmael, William Hawkes, Thomas Webster.
1840. Glasgow ...	Sir John Robinson...................	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.

Date and Place.	Presidents.	Secretaries.
1841. Plymouth...	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester .	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A.	James Thompson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge ..	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S. .	William Betts, Jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robert Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh ..	Rev. Dr. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich......	William Cubitt, F.R.S.	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thompson.
1853. Hull	William Fairbairn, C.E., F.R.S..	James Oldham, J. Thompson, W. Sykes Ward.
1854. Liverpool ...	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, Jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, Jun., H. M. Jeffery.
1857. Dublin	The Right Hon. The Earl of Rosse, F.R.S.	Prof. Downing, W. T. Doyne, A. Tate, James Thomson, Henry Wright.
1858. Leeds.........	William Fairbairn, F.R.S.	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen ...	Rev. Prof. Willis, M.A., F.R.S. .	R. Abernethy, P. Le Neve Foster, H. Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester .	J. F. Bateman, C.E., F.R.S.......	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge ..	William Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle ...	Rev. Prof. Willis, M.A., F.R.S. .	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. A. Tarbottom.
1867. Dundee	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S. ...	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.	P. Le Neve Foster, H. Bauerman.
1870. Liverpool ...	Chas. B. Vignoles, C.E., F.R.S. .	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.

List of Evening Lectures.

Date and Place.	Lecturer.	Subject of Discourse.
1842. Manchester .	Charles Vignoles, F.R.S.	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	Sir R. I. Murchison, Bart.	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.	The Dinornis of New Zealand.
	Prof. Forbes, F.R.S.	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.

Date and Place.	Lecturer.	Subject of Discourse.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.	The Gigantic Tortoise of the Siwalik Hills in India.
1845. Cambridge	G. B. Airy, F.R.S., Astron. Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton	Prof. Owen, M.D., F.R.S.	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S.	Shooting-stars.
	Prof. M. Faraday, F.R.S.	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S.	The Dodo (*Didus ineptus*).
1848. Swansea	John Percy, M.D., F.R.S.	Metallurgical operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S.	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh.	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G. B. Airy, F.R.S., Astron. Roy.	Total Solar Eclipse of July 28, 1851.
1852. Belfast	Prof. G.G. Stokes, D.C.L., F.R.S.	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	Some peculiar phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.	The present state of Photography.
1854. Liverpool	Prof. R. Owen, M.D., F.R.S.	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.
1855. Glasgow	Dr. W. B. Carpenter, F.R.S.	Characters of Species.
	Lieut.-Col. H. Rawlinson	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin	Prof. Thomson, F.R.S.	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L.	Recent discoveries in Africa.
1858. Leeds	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S.	The Fossil Mammalia of Australia.
1859. Aberdeen	Sir R. I. Murchison, D.C.L.	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S.	Electrical Discharges in highly rarefied Media.
1860. Oxford	Rev. Prof. Walker, F.R.S.	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N.	Arctic Discovery.
1861. Manchester	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Roy.	The late Eclipse of the Sun.
1862. Cambridge	Prof. Tyndall, LL.D., F.R.S.	The Forms and Action of Water.
	Prof. Odling, F.R.S.	Organic Chemistry.

Date and Place.	Lecturer.	Subject of Discourse.
1863. Newcastle-on-Tyne.	Prof. Williamson, F.R.S.	The chemistry of the Galvanic Battery considered in relation to Dynamics.
	James Glaisher, F.R.S.	The Balloon Ascents made for the British Association.
1864. Bath	Prof. Roscoe, F.R.S................	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.............	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham.	William Huggins, F.R.S..........	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S..........	Insular Floras.
1867. Dundee......	Archibald Geikie, F.R.S..........	The Geological origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S....	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich	J. Fergusson, F.R.S.	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S.......	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool ...	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connexion with Naval Architecture.

Lectures to the Operative Classes.

1867. Dundee	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich	Prof. Huxley, LL.D., F.R.S. ...	A piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S.	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool ...	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.

Table showing the Attendance and Receipts

Date of Meeting.	Where held.	Presidents.	Old Life Members.	New Life Members.
1831, Sept. 27 ...	York	The Earl Fitzwilliam, D.C.L. ...	...	...
1832, June 19 ...	Oxford	The Rev. W. Buckland, F.R.S. ..	...	...
1833, June 25 ...	Cambridge	The Rev. A. Sedgwick, F.R.S....	...	...
1834, Sept. 8 ...	Edinburgh	Sir T. M. Brisbane, D.C.L.	...	...
1835, Aug. 10 ...	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22 ...	Bristol	The Marquis of Lansdowne	...	...
1837, Sept. 11 ...	Liverpool	The Earl of Burlington, F.R.S. .	...	...
1838, Aug. 10 ...	Newcastle-on-Tyne ..	The Duke of Northumberland...	...	...
1839, Aug. 26 ...	Birmingham	The Rev. W. Vernon Harcourt .	...	...
1840, Sept. 17 ...	Glasgow	The Marquis of Breadalbane ...	...	...
1841, July 20 ...	Plymouth	The Rev. W. Whewell, F.R.S....	169	65
1842, June 23 ...	Manchester	The Lord Francis Egerton	303	169
1843, Aug. 17 ...	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26 ...	York	The Rev. G. Peacock, D.D.	226	150
1845, June 19 ...	Cambridge	Sir John F. W. Herschel, Bart. .	313	36
1846, Sept. 10 ...	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23 ...	Oxford	Sir Robert H. Inglis, Bart.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton ...	149	3
1849, Sept. 12 ...	Birmingham	The Rev. T. R. Robinson, D.D. .	227	12
1850, July 21 ...	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2	Ipswich	G. B. Airy, Esq., Astron. Royal .	172	8
1852, Sept. 1 ...	Belfast	Lieut.-General Sabine, Pres. R.S.	164	10
1853, Sept. 3 ...	Hull	William Hopkins, Esq., F.R.S. .	141	13
1854, Sept. 20 ...	Liverpool	The Earl of Harrowby, F.R.S. ..	238	23
1855, Sept. 12 ...	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D....	182	14
1857, Aug. 26 ...	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22 ...	Leeds	Richard Owen, M.D., D.C.L. ...	222	42
1859, Sept. 14 ...	Aberdeen	H.R.H. The Prince Consort ...	184	27
1860, June 27 ...	Oxford	The Lord Wrottesley, M.A.......	286	21
1861, Sept. 4 ...	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Prof. Willis, M.A. ...	239	15
1863, Aug. 26 ...	Newcastle-on-Tyne ..	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13 ...	Bath	Sir Charles Lyell, Bart., M.A....	287	40
1865, Sept. 6 ...	Birmingham	Prof. J. Phillips, M.A., LL.D....	292	44
1866, Aug. 22 ...	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4 ...	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19 ...	Norwich	Dr. Joseph D. Hooker, F.R.S. .	196	18
1869, Aug. 18 ...	Exeter..................	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14 ...	Liverpool	Prof. T. H. Huxley, LL.D.......	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D....		

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting.			Sums paid on Account of Grants for Scientific Purposes.		
Old Annual Members.	New Annual Members.	Associates.	Ladies.	Foreigners.	Total.	£	s.	d.	£	s.	d.
...	...	...	...	...	353	....			....		
...	...	...	...	...	...	....			....		
...	...	...	...	...	900	....			....		
...	...	...	...	...	1298	....			20	0	0
...	...	...	...	...	...	....			167	0	0
...	...	...	...	...	1350	....			434	14	0
...	...	...	...	...	1840	....			918	14	6
...	...	...	1100*	...	2400	....			956	12	2
...	...	...	...	34	1438	....			1595	11	0
...	...	...	...	40	1353	....			1546	16	4
46	317	...	60*	...	891	....			1235	10	11
75	376	33†	331*	28	1315	....			1449	17	8
71	185	...	160	...	...	....			1565	10	2
45	190	9†	260	...	...	....			981	12	8
94	22	407	172	35	1079	....			830	9	9
65	39	270	196	36	857	....			685	16	0
197	40	495	203	53	1260	....			208	5	4
54	25	376	197	15	929	707	0	0	275	1	8
93	33	447	237	22	1071	963	0	0	159	19	6
128	42	510	273	44	1241	1085	0	0	345	18	0
61	47	244	141	37	710	620	0	0	391	9	7
63	60	510	292	9	1108	1085	0	0	304	6	7
56	57	367	236	6	876	903	0	0	205	0	0
121	121	765	524	10	1802	1882	0	0	330	19	7
142	101	1094	543	26	2133	2311	0	0	480	16	4
104	48	412	346	9	1115	1098	0	0	734	13	9
156	120	900	569	26	2022	2015	0	0	507	15	3
111	91	710	509	13	1698	1931	0	0	618	18	2
125	179	1206	821	22	2564	2782	0	0	684	11	1
177	59	636	463	47	1689	1604	0	0	1241	7	0
184	125	1589	791	15	3139	3944	0	0	1111	5	10
150	57	433	242	25	1161	1089	0	0	1293	16	6
154	209	1704	1004	25	3335	3640	0	0	1608	3	10
182	103	1119	1058	13	2802	2965	0	0	1289	15	8
215	149	766	508	23	1997	2227	0	0	1591	7	10
218	105	960	771	11	2303	2469	0	0	1750	13	4
193	118	1163	771	7	2444	2613	0	0	1739	4	0
226	117	720	682	‡45	2004	2042	0	0	1940	0	0
229	107	678	600	17	1856	1931	0	0	1572	0	0
303	195	1103	910	14	2878	3096	0	0			

* Ladies were not admitted by purchased Tickets until 1843.
† Tickets for admission to Sections only. ‡ Including Ladies.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from 18th August 1869 (commencement of EXETER Meeting) to 14th September 1870 (LIVERPOOL).

RECEIPTS.

		£	s.	d.
To Balance brought from last Account		177	1	0
Received for Life Compositions at Exeter Meeting and since		278	0	0
" Annual Subscriptions, ditto ditto		618	19	7
" Associates' Tickets, ditto ditto		678	0	0
" Ladies' Tickets, ditto ditto		600	0	0
" Dividends on Stock		228	2	6
" Sale of Publications—viz.				
Reports	30 15 4			
Indexes, Catalogue of Stars, &c.	7 5 10			
		38	1	2
" Sale of Consols (£500 Stock)		468	6	0
" per Dr. Perceval Wright, being the balance of a Grant made for investigating the North Greenland Fauna and Flora, but not used		74	18	6
" per Colonel Sykes, being the balance of a Grant made to the Balloon Committee, but not used		38	5	0
		£3199	13	9

Examined and found correct,

G. C. FOSTER,
J. GWYN JEFFREYS, } *Auditors.*
GEO. BUSK,

PAYMENTS.

		£	s.	d.
By Expenses of Exeter Meeting, also Sundry Printing, Binding, Advertising, and Incidental Petty Expenses		358	13	3
" Printing, Engraving, and Binding Report of 38th Meeting, Vol. XXXVII. (Norwich)		660	0	7
" on account of Report of 39th Meeting, Vol. XXXVIII. (Exeter)		26	14	8
" Salaries (1 year)		350	0	0
" Grants made at Exeter Meeting, viz.—				
Maintaining Establishment of Kew Observatory	£600 0 0			
Metrical Committee	25 0 0			
Zoological Record	100 0 0			
Committee on Marine Fauna	20 0 0			
" Ears in Fishes	10 0 0			
" Chemical nature of Cast iron	80 0 0			
" Luminous Meteors	30 0 0			
" Heat in the Blood	15 0 0			
" British Rainfall	100 0 0			
" Thermal Conductivity of Iron &c.	20 0 0			
" British Fossil Corals	50 0 0			
" Kent's Hole Explorations	150 0 0			
" Scottish Earthquakes	4 0 0			
" Bagshot Leaf-Beds	15 0 0			
" Fossil Flora	25 0 0			
" Tidal Observations	100 0 0			
" Underground Temperature	50 0 0			
" Kiltorcan Quarries Fossils	20 0 0			
" Mountain Limestone Fossils	25 0 0			
" Utilization of Sewage	50 0 0			
" Organic Chemical Compounds	30 0 0			
" Onny River Sediment	3 0 0			
" Mechanical Equivalent of Heat	50 0 0			
		1572	0	0
1870. Sept. 14. Balance at London and Westminster Bank	£230 18 6			
" in hands of General Treasurer	1 6 9			
		232	5	3
		£3199	13	9

W. SPOTTISWOODE,
August 18, 1870.

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Report of the Council for the Year 1869–70, *presented to the General Committee at Liverpool, on Wednesday, September* 14*th*, 1870.

The Council have received the usual reports from the General Treasurer and from the Kew Committee. Their reports for the past year will be laid before the General Committee this day.

The Council have to report upon the action they have taken relative to each of the four resolutions referred to them by the General Committee at Exeter.

The first of these resolutions was—

"That the Council be requested to take into their consideration the existing relations between the Kew Committee and the British Association."

The Council accordingly appointed a Committee of their own body to examine into these relations. This Committee had before them a special report drawn up by the Kew Committee, and, after due deliberation, they recommended—

"That the existing relations between the Kew Observatory and the British Association be continued unaltered until the completion, in 1872, of the magnetic and solar decennial period; but that after that date all connexion between them shall cease."

The Council adopted this recommendation, and now offer it, as their own, to the General Committee.

The second resolution referred to the Council was as follows:—

"That the full influence of the British Association for the Advancement of Science should at once be exerted to obtain the appointment of a Royal Commission to consider—

First. The character and value of existing institutions and facilities for scientific investigation, and the amount of time and money devoted to such purposes;

Secondly. What modifications or augmentations of the means and facilities that are at present available for the maintenance and extension of science are requisite; and,

Thirdly. In what manner these can be best supplied."

By a third resolution the Council was "requested to ascertain whether the action of Government in relation to the higher scientific education has been in accordance with the principles of impartiality which were understood to guide them in this matter; and to consider whether that action has been well calculated to utilize and develope the resources of the country for this end, and to favour the free development of the higher scientific education. That the Council be requested to take such measures as may appear to them best calculated to carry out the conclusions to which they may be led by these inquiries and deliberations."

The Committee of the Council appointed to consider these two resolutions

reported their opinion to be favourable to the appointment of a Royal Commission to inquire into the relations of the State to scientific instruction and investigation; and they added that no such inquiry would, in their opinion, be complete which did not extend itself to the action of the State in relation to scientific education, and the effect of that action upon independent educational institutions.

Your President and Council, acting on the advice of this Committee, constituted themselves a Deputation and waited upon the Lord President of the Council. They are glad to be able to report that their efforts to bring this important subject before Her Majesty's Government have been attended with success. On the 18th of May, Her Majesty issued a Commission "to make inquiry with regard to Scientific Instruction and the Advancement of Science, and to inquire what aid thereto is derived from grants voted by Parliament or from endowments belonging to the several universities in Great Britain and Ireland and the colleges thereof, and whether such aid could be rendered in a manner more effectual for the purpose." The Commissioners appointed by Her Majesty are the Duke of Devonshire, the Marquis of Lansdowne, Sir John Lubbock, Bart., Sir James Phillips Kay Shuttleworth, Bart., Bernard Samuelson, Esq., M.P., Dr. Sharpey, Professor Huxley, Dr. W. A. Miller, and Professor Stokes. J. Norman Lockyer, Esq., F.R.S., has been appointed Secretary to the Commissioners, who, up to last July, were engaged taking evidence with great assiduity, and have now adjourned their meetings until November. There is every reason to hope that valuable results will follow from their deliberations.

The fourth resolution which the General Committee referred to the Council was—

"That the rules under which Members are admitted to the General Committee be reconsidered."

A Committee of the Council devoted considerable care to a revision of the existing rules. The modified rules approved by the Council are now submitted for adoption to the present General Committee, whose constitution is, of course, not affected thereby. The most important of the proposed changes are that henceforth new claims to membership of the General Committee shall be forwarded to the Assistant General Secretary at least one month before the next ensuing Annual Meeting of the Association; that these claims shall be submitted to the Council, whose decision upon them is to be final; and that henceforth it is not the authorship of a paper in the Transactions of a scientific society which is alone to constitute a claim to membership of the General Committee, but the publication of any works or papers which have furthered the advancement of any of the subjects taken into consideration at the Sectional meetings of the Society.

Your Council has, also, had under its consideration the desirability of removing certain administrative inconveniences which arise from the circumstance that the next place of meeting is never decided upon by the General Committee until near the close of the actual meeting. They are of opinion that the arrangements of the General Officers would be greatly facilitated, and at the same time the convenience of those who invite the Association consulted, if the General Committee were to decide upon each place of meeting a year earlier than they do at present. In order to make the transition from the existing practice to the proposed one, your Council recommend that two of the invitations which will be received at the present Meeting be accepted, one for 1871, and another for 1872.

It has often been urged that the Association labours under disadvantages

in consequence of its not possessing central offices in London, where its Council and numerous committees could hold their meetings, where the books and memoirs which have been accumulating for years could be rendered accessible to Members, and where information concerning the Association's proceedings could be promptly obtained during the interval between annual meetings. The Council have had the subject under consideration, and in the event of the establishment at Kew being discontinued, they are prepared to recommend that suitable rooms, in a central situation, should be procured. The additional annual expenditure which this would involve would probably not exceed £150.

The Council having been informed by the Local Officers of their desire to have Mr. Reginald Harrison appointed as an additional Local Secretary, to assist in making arrangements for the present Meeting, have nominated that gentleman to the office.

Mr. Arnold Baruchson and Mr. Wm. Crosfield, Jun., have also been nominated Local Treasurers, *vice* Mr. Duckworth resigned.

The Council have added the names of Professor H. A. Newton and Professor C. S. Lyman, who were present at the Exeter Meeting, to the list of Corresponding Members.

Report of the Kew Committee of the British Association for the Advancement of Science for 1869–70.

The Committee of the Kew Observatory submit to the Council of the British Association the following statement of their proceedings during the past year:—

At the Meeting of the General Committee at Exeter it was resolved that the existing relations between the Kew Committee and the British Association be referred to the Council to report thereon.

In consequence of this resolution, the Kew Committee on the 23rd November, 1869, prepared for the information of the Council a statement on the past and present condition of the Observatory, which was presented to the Council on the 11th December.

In this statement it was shown that while the establishment at Kew Observatory received its main support from the British Association, and was under the control of that body, yet much of the apparatus in use at Kew was furnished from other sources. Thus the Royal Society had from the Government-Grant Fund supplied the establishment with the apparatus for testing Barometers, with that for testing Sextants, with the dividing-machine for constructing Standard Thermometers, and also with the set of Self-recording Magnetographs at present in use, while from the Donation Fund they had furnished the Photoheliograph and the Whitworth lathe and planing-machine.

The Royal Society had likewise defrayed from the Donation Fund the expense of introducing gas into the Observatory, and of building a house for the verification of magnetic instruments, besides which they had borne from the Government-Grant Fund since 1863 the whole expense of working the Photoheliograph (including the purchase of a Chronometer) and of reducing its results.

The instruments used at Kew for determining the absolute magnetic elements are the property of Her Majesty's Government, and have been lent

to the Kew Observatory by the Magnetic Office at Woolwich, under the direction of Sir E. Sabine, and many of those magnetic instruments with which Kew has been the means of furnishing scientific travellers have been derived from the same source.

Of late Kew has become the Central Observatory of the Meteorological Committee, and a commodious workshop has been erected near the Observatory by that Committee, since otherwise the main building would have been too small for the access of work consequent upon the arrangement entered into.

The statement prepared by the Kew Committee contained likewise a summary of the scientific work done at the Observatory, as well as some interesting historical remarks connected with the origin of the establishment, drawn up by Sir C. Wheatstone, and in this shape it was submitted to the Council of the British Association.

The Council decided to recommend "that the present relations between the Kew Observatory and the British Association be continued unaltered until the completion, in 1872, of the magnetical and solar decennial period; that after that date all connexion between them should cease."

In consequence of this recommendation, the Kew Committee were led to contemplate the dissolution of the Kew establishment in 1872, and they became anxious to make such arrangements as might enable them to complete their scientific labours in a creditable manner before the time of the anticipated dissolution. The magnetic work in particular caused them anxiety; for the annual income of the establishment is insufficient to permit of that work being fully completed by the time of the Annual Meeting of the Association in 1872. Under these circumstances the Chairman offered to supplement the deficiency (see Appendix, p. lvi). It will be seen by this Report that the magnetical tabulations and reductions are now proceeding very fast.

The recommendation of the Council was also a matter of anxiety to the Superintendent, Mr. Stewart; and as the Professorship of Natural Philosophy at Owens College, Manchester, became vacant about this time, he applied for the appointment and was successful in obtaining it.

This will render it necessary for Mr. Stewart to reside in Manchester, but the staff at the Observatory are such that Mr. Stewart will undertake by their aid to assist the Committee in the superintendence of the work of the Observatory until 1872.

(A) Work done by Kew Observatory under the direction of the British Association.

1. *Magnetic Work.*—In the present state of magnetical science it would appear to be desirable to preserve as completely as possible the details of observations, so that future theorists may have a large and valuable source of information by which to test their speculations.

The Committee are therefore desirous that by the autumn of 1872 a manuscript record should be completed, containing all the hourly tabulated values from the Kew Magnetographs arranged in monthly tables.

This record should be carefully preserved, along with the original photographic traces, in the Archives of the Association.

Pursuing the method indicated by Sir E. Sabine, and adopting the separating values finally determined by him, the Committee further propose to obtain monthly results indicating the following points for each of the three magnetic elements, distributed according to the hour of the day:—

1. Aggregate of disturbance tending to increase the numerical values.
2. Aggregate of disturbance tending to decrease the same.
3. Solar-diurnal range of the undisturbed observations.

They suggest that the monthly results embodying these facts should be published in detail.

Finally, they propose to continue the discussion of the Lunar-Diurnal variations commenced by Sir E. Sabine, and carried on by him up to the end of the year 1864. In order to work this scheme with sufficient rapidity to complete it before the autumn of 1872, additional assistance has been procured, the expense of which has been defrayed by the Chairman. Mr. Whipple, Magnetical Assistant, has displayed much zeal and ability in organizing the work and in superintending its immediate execution.

Already the hourly numerical values of the three magnetic elements have been obtained and tabulated in monthly forms from the commencement of the series in 1858 to the present date; and considerable progress has also been made in the next step of the reduction.

A Unifilar, formerly employed by Captain Haig, and of which the constants have been determined at the Observatory, has been lent to Lieut. Elagin, of the Russian Navy, for use in the Japanese seas and elsewhere.

A Dip-circle by Dover has been verified and sent to Prof. Jelinek, of Vienna, and another, by the same maker, has been verified for Dr. A. B. Meyer, for use in the East Indies. This gentleman has likewise received magnetic instruction at the Observatory.

A Dip-circle by Adie, furnished with a deflecting cylinder apparatus, has been verified and dispatched to Prof. Bolzani, of the University of Kasan.

Three Dipping-needles have likewise been constructed for Dr. Bergsma, of Batavia, and one for Mr. Chambers, of the Colaba Observatory, Bombay.

A Deflection-bar has been procured and verified for the Russian Central Observatory. A Declinometer has been sent to the Lisbon Observatory, and a Fox's Circle has been lent to Dr. Neumayer, after having been repaired by Adie.

The instrument devised by Mr. Broun for the purpose of estimating the magnetic dip by means of soft iron, and constructed at the expense of the British Association in pursuance of a resolution of that Body passed at the Oxford Meeting, has been forwarded to that gentleman at his request.

The usual monthly absolute determinations of the magnetic elements continue to be made by Mr. Whipple, Magnetic Assistant.

A paper embodying the results of the absolute observations of Dip and Horizontal Force, made at Kew from April 1863 to April 1869, has been communicated by the Superintendent to the Royal Society, and published in the 'Proceedings' of that body. The results obtained evidence the accuracy with which the monthly observations have been made by Mr. Whipple.

The Self-recording Magnetographs are in constant operation as heretofore, also under his charge; and the photographic department connected with these instruments remains under the charge of Mr. Page.

2. *Meteorological work.*—The meteorological work of the Observatory continues in the charge of Mr. Baker.

Since the Exeter Meeting, 150 Barometers have been verified, and 30 have been rejected; 1160 Thermometers and 103 Hydrometers have likewise been verified. Nineteen Standard Thermometers have been constructed for Prof. Tait, and two for the Meteorological Office.

The self-recording meteorological instruments now in work at Kew will

be again mentioned in the second division of this Report. These are in the charge of Mr. Baker, the photography being superintended by Mr. Page.

3. *Photoheliograph.*—The Kew Heliograph, in charge of Mr. Warren De La Rue, continues to be worked in a satisfactory manner. During the past year 351 pictures have been taken on 237 days.

It was considered desirable that six prints should be obtained from each of the negatives of the sun-pictures taken at the Observatory during the whole time that the Photoheliograph should remain at work, which will probably be from February 1862 to February 1872.

In order to accomplish this, an outlay of £120 spread over two years was found to be necessary, and this sum has been voted from the Donation Fund of the Royal Society.

A large number of these prints has already been obtained, and it is proposed to present complete sets to the following institutions:—

The Royal Astronomical Society,
The Imperial Academy of Paris,
The Imperial Academy of St. Petersburg,
The Royal Society of Berlin,
The Smithsonian Institution, United States,

leaving one set for the Royal Society.

A paper embodying the positions and areas of the sun-groups observed at Kew during the years 1864, 1865, and 1866, as well as fortnightly values of the spotted solar area from 1832 to 1868, has been communicated to the Royal Society by Messrs. Warren De La Rue, Stewart, and Loewy.

This paper is in the course of publication in the Philosophical Transactions, and will shortly be distributed.

A Table exhibiting the number of sun-spots recorded at Kew during the year 1869, after the manner of Hofrath Schwabe, has been communicated to the Astronomical Society, and published in their Monthly Notices.

M. Otto Struve, Director of the Imperial Observatory at Pulkowa, visited England in the month of August last. He brought with him, for the Kew Observatory, some sun-pictures made at Wilna with the photoheliograph, which, it will be recollected, was made some years ago, under the direction of Mr. De La Rue, by Mr. Dallmeyer. This instrument combines several important improvements on the original Kew model, the value of which is forcibly brought out in the superior definition of the Wilna sun-pictures. As, however, the series of the ten-yearly record at Kew was commenced with the instrument as originally constructed, it was not deemed desirable to alter it in any way until the series had been completed and reduced, and the corrections for optical distortion ascertained and applied. In the event of the sun-work being continued after 1872, it will be desirable to do so with a new and improved heliograph.

M. O. Struve proposed to exchange the complete series of pictures obtained at Wilna for that made at Kew. He also stated that it is contemplated to erect a second heliograph at the Central Observatory at Pulkowa.

4. *Miscellaneous Work.*—A few experiments have been made on the rotation of a disk *in vacuo*. By an arrangement devised by Mr. Beckley, a very perfect carbonic-acid vacuum has been obtained, the residual pressure being 0·02 inch as indicated by a mercurial gauge with a contracted tube, but it was believed that the vacuum was even more perfect.

A disk of paper and one of ebonite gave very sensible heat effects in such a vacuum, and it was hoped that the experiments might have been satisfac-

torily completed; but while they were in progress the pressure of the outer atmosphere shattered the receiver into a number of pieces, fortunately without any injury to the experimenters.

Another receiver has now been made, and it is purposed in future to use it with a cover.

A Transit instrument has been lent to Mr. G. J. Symons, and one Sextant has been verified.

(B) Work done at Kew as the Central Observatory of the Meteorological Committee.

It is stated in the Report for 1867 that the Meteorological Committee had appointed Mr. Balfour Stewart as their Secretary, on the understanding that he should, with the concurrence of the Kew Committee, retain his office of Superintendent of the Kew Observatory.

On the 8th October, 1869, Mr. Stewart resigned his appointment as Secretary to the Meteorological Committee and Director of their Central Observatory—a step which took effect on 31st of March, 1870, and which was followed by a modification of the relation between the two Committees.

The Meteorological Committee, at their Meeting on 12th November, 1869, resolved that they were prepared to make the following proposals to the Council of the British Association:—

I. That Kew be continued as one of the ordinary self-recording observatories, in which case the Committee would be prepared to allot to it annually £250; or,

II. In addition to the foregoing work, that Kew be maintained as the central observatory for examination of records and tabulations from all the other observatories, in which case the Committee will be prepared to allot a further annual sum of £400.

The Kew Committee having been furnished with this resolution of the Meteorological Committee, resolved that it be recommended to the Council of the British Association that Kew be continued for the next two years as one of the ordinary self-recording observatories of the Meteorological Committee, that body allowing it annually £250; and that, in addition, it be maintained as the central observatory for the examination of the records and tabulations from all the other observatories, for the further sum of £400 per annum. This arrangement was approved by the Council; and it was thereupon resolved by the Kew Committee, that out of the £650 received from the Meteorological Committee, £200 be given to Mr. Stewart for superintending the meteorological work of the Observatory, this resolution to take effect after 31st March, 1870.

1. *Work done at Kew as one of the Observatories of the Meteorological Committee.*—The Barograph, Thermograph, and Anemograph furnished by the Meteorological Committee are kept in constant operation. Mr. Baker is in charge of these instruments. From the first two instruments traces in duplicate are obtained, one set being sent to the Meteorological Office and one retained at Kew; as regards the Anemograph, the original records are sent, while a copy by hand of these on tracing-paper is retained. The tabulations from the curves of the Kew instrument are made by Messrs. Baker, Page, and Foster.

2. *Verification of Records.*—The system of Checks devised by the Kew Committee for testing the accuracy of the observations made at the different Observatories continues to be followed, the only alteration being that the Kew

Staff, at the suggestion of the Meteorological Office, have undertaken to rule on the Barograms and Thermograms a set of zero lines, which are of great use in Pantagraphic operations.

Mr. Rigby continues to perform the main part of this work; Mr. Baker, Meteorological Assistant, having the general superintendence of the department.

3. *Occasional Assistance.*—The Meteorological Committee have availed themselves of the permission to have the occasional services of Mr. Beckley, Mechanical Assistant at Kew; and he has lately been visiting the various observatories of the Meteorological Committee.

The Self-recording Rain-gauge mentioned in last Report as having been devised by Mr. Beckley has been adopted by the Meteorological Committee, and instruments of this kind are at present being constructed for their various Observatories.

The Staff at Kew continue to make occasional absolute hygrometrical observations by means of Regnault's instrument, with the view of testing the accuracy of the method of deducing the dew-point from the observations with the dry- and wet-bulb thermometers.

Two erections have been made in the grounds adjoining the Observatory; and on one of these a large Robinson's Anemometer is placed, while a small instrument of the same kind is placed on the other.

By this means the indications of the large and those of the small-sized instrument may be compared with each other. The cost of this experiment has been defrayed by the Meteorological Committee.

J. P. GASSIOT,
Chairman.

Kew Observatory,
9th September, 1870.

Appendix to Kew Report of 9th September, 1870.

At the Meeting of the Kew Committee held at Burlington House on 2nd March 1870, it was Resolved that the remarks by Sir E. Sabine and Mr. Stewart be printed, along with extracts from the Report for 1866–67, and from the Minutes of June 18, 1869; and that copies be forwarded to the several Members of the Committee, with a statement by Mr. Stewart as to the manner in which he proposes to complete the reductions, so as to carry out the Resolutions of the Committee.

No. 1.

Memorandum by General Sir E. Sabine regarding the Investigations for which the loan of the Kew Photograms from 1857 to 1862 was requested.

March 1, 1870.

The photograms here referred to were duly received at Woolwich, and duly returned to Kew; Mr. Gassiot has a paper stating the dates at which the several photograms were returned to Kew.

The investigations for which these documents were temporarily borrowed formed the substance of a paper presented to the Royal Society in June 1863, and printed in the Philosophical Transactions of that year (Art. XII.). The

1st Section contained a Tabular Synopsis of *ninety-five* of the principal disturbances of the Declination recorded by the Kew photograms from January 1858 to December 1862, with a comparison of the Laws of the Disturbances derived therefrom with the Laws derived by the more usual method then practised. The tabular summary at the close of Section 1 shows the resulting aggregate values both of Easterly and of Westerly disturbance at each of the 24 hours (or at 24 equidistant epochs) in each of the five years, as well as in the whole period. It is strictly a tabular detail for the period in question, showing the *Disturbance-diurnal Variation* as it would result if the investigation were limited to the 95 most disturbed days, and may be considered to represent the mode of investigation then practised by some magneticians.

The 2nd Section of the paper compared the Laws of the Disturbances thus obtained with the Laws derived from a wider selection of disturbed observations; *i. e.* a selection including every anomalous record of which the anomalous character cannot with probability be ascribed to any other source than that of the disturbing action whose laws are sought. This Section is also accompanied by a tabular statement in full detail; and from an examination of the contents of the 1st and 2nd Sections the following conclusions are drawn:—

1. That the disturbances have *systematic laws*:
2. That both easterly and westerly deflections have each their own systematic laws, distinct and different each from the other:
3. That the laws are approximately the same, whether derived from the more limited or the more extended selection, though the latter comprises three times as many cases of disturbance as the former.

Hence it is inferred that, by taking into account only the most notable days of disturbance (as was then the practice of some magneticians), an *approximately* correct view of the disturbance-diurnal variation may be obtained; but, if we desire to eliminate the influence of the disturbances on the diurnal variation due to other causes, the more comprehensive method must be adopted.

A selection of this latter character was then made for the five years 1858 to 1862, and the results exhibited, both in tabular and graphical representations; and the laws derived therefrom were compared with corresponding investigations in other parts of the globe.

In the 4th Section of the paper is discussed the "Diurnal Inequality," comprehending 1°, the disturbance-diurnal variation, and 2°, the undisturbed solar-diurnal variation. This discussion may be regarded as exhibiting what should be the *primary step* in the analysis of the periodical variations.

The solar-diurnal variation derived from the record of the five years at Kew, 1858 to 1862, is then compared with solar-diurnal variations similarly obtained at Toronto, Nertschinsk, Pekin, St. Helena, the Cape of Good Hope, and Hobarton; and the several points of agreement or difference are discussed.

In the same 4th Section, the *semiannual inequality* which is seen to exist at all the stations enumerated above is discussed, and is shown to manifest a *solar* influence, evidenced by the differences exhibited in different parts of the globe.

In Section 6 the *Lunar-diurnal Variation* derived in each of the five years at Kew is deduced and discussed.

In Section 7 the *Secular Change* and *Annual Variation* of the Declination

are discussed, and a *semiannual variation* is shown to exist having epochs coincident (or nearly so) with the equinoxes—a conclusion which is shown to be in accordance with similar investigations at Hobarton, St. Helena, and the Cape of Good Hope.

The 8th Section establishes the existence of an "annual variation" or "semiannual inequality" of the *Inclination* and of the *horizontal and total* Forces, derived from the observations made at Kew in 1858 to 1862, with instruments which had been supplied by the Magnetic Office at Woolwich, and employed by Mr. Chambers at Kew. The calculation of the Kew results made at the Woolwich Office was shown to be in accordance with the phenomena at Hobarton, St. Helena, and the Cape of Good Hope.

A subsequent paper, communicated by me to the Royal Society in 1866, contained the *Lunar-diurnal* Variation of the three magnetic elements derived from the Kew photograms from January 1858 to December 1864, being an extension of two years upon the records discussed in the former paper, and limited only by the epoch to which the photograms had then been carried, *i. e.* to the close of 1864. The general agreement of the Kew results with those derived at Hobarton and Philadelphia was satisfactorily established by the discussion of the Kew records up to the date of December 1864, and several points of difference in minor respects, requiring further investigation, were indicated: for these the continuation of the Kew photograms, subsequently to December 1864, may be expected to supply the materials.

(*a*)

What appears now to be required is the continuation of the same process of examination, and comparison with the results obtained at other stations, of the results derivable from the Kew photograms in the years which have elapsed since the investigations were completed of which an account had thus been given.

These additional years are from December 31, 1864, to December 31, 1869, *i. e.* five years. And this is the work which, if I correctly understood the resolution of the Kew Committee, passed (I think) at the Meeting before the last (viz. in June 1869), the Superintendent was requested to proceed with.

EDWARD SABINE.

J. P. Gassiot, Esq.,
Chairman of the Kew Committee.

No. 2.

Suggestions by Mr. Stewart as to the best form of Publication of the Results derived from the Traces of the Kew Magnetographs.

IN the present state of magnetical science, it would appear to be desirable to preserve as completely as possible the details of the original observations,—a course similar to that which has been pursued by Dr. Neumayer in his description of the results of the Flagstaff Observatory, Melbourne.

Photographic Traces.

The original documents of the Kew Observatory are the photographic traces. As these are supposed to be liable to fade in the course of time, I would suggest that a careful copy of them on tracing-paper would be the simplest and least expensive mode of retaining them. Such a copy would not be sufficiently accurate for investigations regarding peaks and hollows,

but these phenomena will, it is hoped, be investigated before the time when the Observatory ceases to be connected with the British Association.

The curves are as yet all in good order. The whole expense of preserving traces would probably not much exceed £100. And I would suggest that I might with propriety direct to this object a grant of £100 which I have at present in hand from the Royal Society for procuring impressions of magnetic curves.

(b) *Hourly Tabulations from Traces.*

The documents next in order are the hourly tabulated numerical values, as exhibited in monthly tables for each of the elements. Although individual results of this nature have been published by Dr. Neumayer, the cost of the publication of the Kew series in this country would be very great; and bearing in mind the limited reference to such individual results, I would suggest that a carefully preserved manuscript record would probably be sufficient.

(c) *Separation of Disturbances and Solar-Diurnal Variations.*

Pursuing the method indicated by Sir E. Sabine, and adopting the separating value finally determined by him, we should obtain monthly results indicating the following points for each of the three elements, distributed according to the hour of the day:—

1. Aggregate of disturbances tending to increase the numerical values.
2. Aggregate of disturbances tending to diminish the same.
3. Solar-diurnal range of the undisturbed observations.

I would suggest that the monthly results embodying these facts should be published in detail. The publication would not probably occupy more than thirty-six quarto pages well filled with figures.

Lunar-Diurnal Variations.

Adopting Sir E. Sabine's method of treating these, I would suggest, in addition, a classification according to the relative position of the sun and moon. We might perhaps have quarterly means of lunar days, each quarter being divided into four groups representing the four well-known relative positions of the sun and moon.

This might occupy about fifteen quarto pages well filled with figures.

(d) *Secular Change and Semiannual Inequality.*

Presuming that these elements are best determined for the two components of magnetic force from the absolute observations, I would suggest that, as regards the declination, Sir E. Sabine's plan be pursued. As he has already given the details of his results up to the end of 1863, it would only be necessary to continue these up to the time when the series is complete.

Remarks on the above.

If a condensed series of results be published as above, and if, in addition, the traces and hourly observations be preserved, as is suggested, future theorists would have a large and valuable source of information by which to test their speculations. I should be happy, had I the opportunity of using such a series, to discuss it after the manner that Sir E. Sabine has indicated in the very valuable papers which he has presented to the Royal Society.

No. 3.

Memorandum containing extracts from the Minutes of the Kew Committee relating to Magnetic Reductions, and containing also an estimate of the probable Expense of carrying out the list of suggestions (paper No. 2).

Kew Observatory,
4th March, 1870.

My dear Sir,

In accordance with the wish expressed at the last Meeting of the Kew Committee for full information regarding the present state of the magnetic reductions, I beg to send you the following statement:—

The first extract bearing on this subject is one from the Report of the Kew Committee to the Aberdeen Meeting of the British Association. It is as follows:—

"As the staff of assistants at the Observatory is not sufficiently large to "undertake these tabulations, General Sabine has undertaken to have the "results tabulated at Woolwich for every hour."

In a scheme for the working of the Observatory after it became the central Observatory of the Meteorological Committee, I suggested that it would be very desirable to undertake the tabulation and reduction of the magnetic curves.

Simultaneously with this scheme, their Report to be presented to the Meeting of the Association in 1867 was discussed by the Kew Committee, and in the Report the following statement occurs:—

"The magnetic curves produced at Kew previously to the month of "January 1865 have all been measured and reduced, under the direction of "General Sabine, by the staff of his office at Woolwich; and the results of "this reduction have been communicated by General Sabine to the Royal "Society in a series of interesting and valuable memoirs. It is now pro-"posed that the task of tabulating and reducing these curves since the above "date be performed by the staff at Kew working under the direction of Mr. "Stewart."

In accordance with this resolution, the magnetic tabulations were proceeded with as fast as the funds at the disposal of the Observatory would allow, and the exact progress made was from time to time reported to the Committee.

In my Report to the Meeting of the Kew Committee held on June 18, 1869, the following passage occurs:—

"In the present organization of the Observatory, it is the surplus funds "that are devoted to magnetic reductions; but it will hardly be possible be-"fore the yearly accounts are closed to state the probable amount of the "surplus.

"It is, however, imagined that if the probable surplus for the year "1869–70 be anticipated and devoted to tabulation while the summer wea-"ther lasts, then before the end of next winter session the reductions will "be very far advanced for all of the three magnetic elements."

At the same Meeting the following resolution was passed:—

Resolved,—"That Mr. Balfour Stewart be authorized to apply the sur-"plus funds in his hands to the tabulation and reduction of the magnetic

"photographic records; and that he be requested to have the work done "with as much rapidity as is consistent with accuracy—the final reduction "to include both monthly and annual means, but in the first instance the "phenomena of the disturbances from 1863 to 1870 to be proceeded with.

"In reference to Mr. Balfour Stewart's proposal that a more intimate "comparison between solar and magnetic records be made, it was resolved "that he be requested to prepare such a comparison for one magnetic ele- "ment, for a whole period of solar disturbance, for the consideration of the "Committee."

From all these extracts it will, I think, appear that the Committee considered that they would have funds sufficient to tabulate and reduce the magnetic curves since the beginning of 1865, the date at which Sir E. Sabine left off tabulating, and that any resolution having reference to curves of a previous date did not contemplate any retabulation of such curves. I conceive, therefore, that at present I am under obligation to tabulate and reduce the curves obtained since the beginning of 1865, the Committee acting on the supposition that the funds which accrue to the Observatory from various sources are sufficient for this purpose. If, however, the Committee should consider that, in addition to this, it would be desirable to systematize the whole Kew results after the method indicated in the suggestions by me which accompany this letter, it would be quite possible to accomplish this work before 1872, and to do so without materially interfering with the work of the Observatory; but it would require additional funds for the purpose; in fact, the question resolves itself into one of expense. The following estimate, prepared by Mr. Whipple, and revised by me, will give a tolerably good idea of the probable expense of doing this:—

(*e*)

	£	s.	d.
Purchase of two new Tabulating instruments and fittings	30	0	0
Measurement of curves to $\frac{1}{1000}$ of an inch from Jan. 1, 1858, to Dec. 31, 1864	143	14	0
Subsidiary measurements	63	0	0
Copying out and systematizing results	126	0	0
Extraction of disturbances	100	0	0
Paper and forms	10	0	0
	472	14	0

This sum would probably enable all these suggestions to be complied with, except those relating to the means connected with the lunar-diurnal variations. The production of such means since 1865 will, of course, form part of the reductions at present in hand, and it would be very easy to give the tables such a shape as to exhibit a classification according to the relative position of the sun and moon. If the results of this proved sufficiently valuable, the same classification might be afterwards extended to the results previous to 1865, provided the details of such results have been obtained and preserved by means of the outlay of £472 14*s*., as mentioned above. This particular form of reduction does not appear so pressing; and as it would cost £130 to recast the individual results previous to 1865 into the precise form of lunar tables mentioned in the suggestions, this matter may be allowed to wait.

But the other matters mentioned in these suggestions are, I think, of greater importance, more especially as, in the very valuable paper of results produced by Sir E. Sabine, there would appear to have been contemplated an exhibition to the world of the most valuable and important facts derived from the Kew results, rather than an exhaustive reduction of the same (see paper No. 1). The Committee might, therefore, if the above outlay were incurred, exhibit the distribution over the various months of every year of the disturbed observations for the whole Kew series, and also exhibit the solar-diurnal variations of the horizontal and the vertical force.

If it be allowable to devote to this purpose £100 which I have in hand from the Royal Society, it would so far lessen the expense, and in this case £400 might be regarded as the extreme limit of what would be incurred.

I remain,
Yours very truly,
B. Stewart.

J. P. Gassiot, Esq.,
Chairman of the Kew Committee.

Extracts from Minutes of Kew Committee held at Burlington House on 9th March, 1870, Present Mr. Gassiot (in the Chair), Sir E. Sabine, Sir C. Wheatstone, Col. Strange, Dr. Miller, Mr. Galton, Mr. De La Rue, Mr. Spottiswoode.

"Resolved,—That the following work be executed at Kew, under the " superintendence of Mr. Stewart.

"*Current Work.*

"The work as defined in paragraph marked (*a*), page lii (General Sabine's " Memorandum).

"*Arrears of Work.*

"1st. Hourly tabulations from traces as defined in paragraph marked (*b*), " page liii (Mr. Stewart's statement).
"2nd. Separation of disturbances and solar-diurnal variations, para- " graph (*c*), page liii.
"3rd. Secular change and semiannual inequality, paragraph (*d*), page " liii.
"These arrears to be executed in accordance with the estimate (*e*), page lv."

It appearing that the only sum at the disposal of Mr. Stewart for back magnetic work was £100, Mr. Gassiot offered to supplement the difference required, provided the sum required from him did not exceed £400.

Resolved unanimously,—"That the Committee accept with thanks the " munificent offer of their Chairman, and that Mr. Stewart be empowered " to proceed with the work on the understanding that the total cost shall " not exceed £500."

Accounts of the Kew Committee of the British Association from August 18, 1869, *to September* 14, 1870.

RECEIPTS.

				£	s.	d.
Balance from last account				46	16	4
Received from the General Treasurer				600	0	0
For the verification of Meteorological Instruments:—						
From the Meteorological Office	69	9	0			
From the Office of Standards	2	1	0			
From Opticians and others	56	16	0			
				128	6	0
For the verification of Magnetical Instruments				5	10	0
For the construction of Standard Thermometers				20	0	0
From the Meteorological Office:—						
Allowance for one year as one of the Observatories of the Meteorological Committee	250	0	0			
Extra allowance to Kew as Central Observatory:—						
From October 1st, 1869, to March 31st, 1870, at £200 per annum	100	0	0			
From April 1869 to 30th September 1870, at £400 per annum	200	0	0			
For services of assistants	17	10	0			
				567	10	0
From sale of Photographic residues				4	17	1
Deficiency made up by the Chairman				202	11	7
				£1575	11	0

PAYMENTS.

				£	s.	d.
Salaries, &c.:—						
To B. Stewart, four quarters, ending 30th September, 1870	200	0	0			
Ditto, allowance for superintending work connected with the Meteorological Committee, from April 1st, 1870, to September 30th, 1870	100	0	0			
Ditto, allowance for petty travelling expenses	10	0	0			
G. Whipple, salary to quarter ending 30th September, 1870	125	0	0			
T. Baker, do. do.	100	0	0			
F. Page, do. do.	70	0	0			
J. Rigby, do. do.	60	0	0			
R. Beckley, salary from August 16th, 1869 to August 15th, 1870	130	0	0			
J. Foster, salary from June 5th, 1869, to September 30th, 1870	51	11	0			
A. Hill, salary from June 5th, 1869, to July 30th, 1870	28	12	0			
				875	3	0
Apparatus, Materials, Tools, &c.				67	17	1
Ironmonger, Carpenter, and Mason				25	19	1
Printing, Stationery, Books, Postage, &c.				50	0	1
Gas and Coals				75	16	9
House Expenses, Chandlery, &c.				71	9	6
Porterage and petty expenses				46	2	11
Meteorological work done at extra hours				33	18	0
Magnetical tabulations done by supernumerary assistants				318	4	7
Rent of Land attached to Observatory				11	0	0
				£1575	11	0

Examined with the vouchers and found correct.

August 29th, 1870.

W. J. SMYTHE, Colonel.

Recommendations adopted by the General Committee at the Liverpool Meeting in September 1870.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Applications involving Grants of Money.

That the sum of £600 be placed at the disposal of the Council for maintaining the establishment of the Kew Observatory.

That the Committee for reporting on the Rainfall of the British Isles be reappointed, and that this Committee consist of Mr. Charles Brooke, Mr. Glaisher, Professor Phillips, Mr. G. J. Symons, Mr. J. F. Bateman, Mr. R. W. Mylne, Mr. T. Hawksley, Professor Adams, Mr. C. Tomlinson, Professor Sylvester, Dr. Pole, and Mr. Rogers Field; that Mr. G. J. Symons be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That the Committee on Underground Temperature, consisting of Sir William Thomson, Dr. Everett, Sir Charles Lyell, Bart., Mr. J. Clerk Maxwell, Professor Phillips, Mr. G. J. Symons, Mr. Balfour Stewart, Professor Ramsay, Mr. Geikie, Mr. Glaisher, Rev. Dr. Graham, Mr. E. W. Binney, Mr. George Maw, Mr. Pengelly, and Mr. S. J. Mackie, be reappointed with the addition of the name of Mr. Edward Hull; that Dr. J. D. Everett be the Secretary, and that the sum of £150 be placed at their disposal for the purpose.

That the Committee on the Thermal Conductivity of Metals, consisting of Professor Tait, Professor Tyndall, and Dr. Balfour Stewart be reappointed; that Professor Tait be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That the Committee on Tides, consisting of Sir W. Thomson, Professor Adams, Professor W. J. M. Rankine, Mr. J. Oldham, Rear-Admiral Richards, and Mr. W. Parkes be reappointed, and that the sum of £100 be placed at their disposal for the purpose.

That the Committee on Luminous Meteors, consisting of Mr. Glaisher, Mr. R. P. Greg, Mr. Alexander Herschel, and Mr. C. Brooke be reappointed, and that the sum of £30 be placed at their disposal for the purpose.

That Mr. Edward Crossley and Rev. T. W. Webb be a Committee for discussing Observations of Lunar Objects suspected of change; that Mr. Crossley be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Sir J. Herschel, Bart., and Professor Erman be a Committee for the purpose of procuring the Recomputation by Professor Petersen of the Gaussian Constants for 1839, so as to make the additional available observations, and that the sum of £50 be placed at their disposal for the purpose.

That Professor Balfour Stewart, Mr. Latimer Clark, and Mr. C. T. Varley be a Committee for the purpose of investigating the best method of Measuring Electrical Capacity, and of constructing Standard Measures of Capacity; that Prof. Balfour Stewart be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Professor Sir William Thomson, Mr. J. Clerk Maxwell, and Professor Fleeming Jenkin be a Committee for the purpose of investigating the bes method of measuring differences of Electrical Potential, and issuing a Stan-

dard Potential Gauge; that Professor Fleeming Jenkin be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Mr. Hockin, Dr. Matthiessen, and Prof. A. W. Williamson be a Committee for the purpose of investigating the best method of measuring Electrical Currents and constructing a Standard Electrodynamometer; that Mr. Hockin be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That it be an instruction to each of the three last-named Committees, that it shall carry out the system adopted by the Electrical Standards Committee, and that these Committees have the use of all instruments hitherto constructed with the Funds of the Association.

That Professor A. W. Williamson, Professor Frankland, Professor Roscoe, and Professor Odling be a Committee for the purpose of superintending the publication of the Monthly Reports of the Progress of Chemistry by the Chemical Society, and that the sum of £100 be placed at their disposal for the purpose.

That Professor A. Crum Brown, Professor Tait, and Mr. Dewar be a Committee for the purpose of carrying on the researches of Mr. Dewar on the Thermal Equivalents of the Oxides of Chlorine, and that the sum of £25 be placed at their disposal for the purpose.

That Sir Charles Lyell, Bart., Professor Phillips, Sir John Lubbock, Bart., Mr. John Evans, Mr. Edward Vivian, Mr. William Pengelly, Mr. George Busk, Mr. W. Boyd Dawkins, and Mr. W. Ayshford Sandford be a Committee for the purpose of continuing the exploration of Kent's Cavern, Torquay; that Mr. Pengelly be the Secretary, and that the sum of £150 be placed at their disposal for the purpose.

That Dr. P. M. Duncan and Professor Ansted be a Committee for the purpose of continuing Researches on British Fossil Corals; that Dr. P. M. Duncan be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That the Rev. W. S. Symonds, Mr. Lightbody, and the Rev. J. B. La Touche be a Committee for the purpose of continuing to estimate the quantity of Sedimentary deposits in the river Onny; that the Rev. J. B. La Touche be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Mr. W. S. Mitchell, Mr. Henry Woodward, Mr. Robert Etheridge, Mr. G. Maw, and Mr. W. Carruthers be a Committee for the purpose of continuing to investigate the Leaf-beds of the Lower Bagshot Series of the Hampshire Basin; that Mr. Mitchell be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Mr. James Thomson and Professor Harkness be a Committee for the purpose of slicing Fossil Corals, in order to show their structure by means of Photography; that Mr. Thomson be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Mr. Robert H. Scott, Dr. J. Hooker, Dr. E. P. Wright, and Sir W. Trevelyan, Bart. be a Committee for the purpose of exploring the Mesozoic Deposits of Omenak and other Localities in North Greenland; that Mr. Scott be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That Mr. Henry Woodward, Dr. Duncan, and Mr. Robert Etheridge be a Committee for the purpose of carrying on researches in the British Fossil Crustacea; that Mr. Woodward be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Mr. G. Busk and Mr. Boyd Dawkins be a Committee for the purpose of assisting Dr. Leith Adams in the preparation of plates illustrating an account of the Fossil Elephants of Malta; that Mr. Busk be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Dr. J. D. Hooker, Mr. W. Carruthers, and Professor Balfour be a Committee for the purpose of continuing investigations into the Fossil Flora of Britain; that Mr. Carruthers be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Dr. Sharpey, Dr. B. W. Richardson, and Professor Humphry be a Committee for the purpose of continuing researches on the physiological action of the Methyl and other allied compounds; that Dr. Richardson be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Mr. Sclater, Dr. Günther, Professor Newton, Mr. Newton, and the Rev. H. B. Tristram be a Committee for the purpose of continuing a record of Zoological Literature; that Mr. Sclater be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Prof. M. Foster, Dr. Arthur Gamgee, and Mr. E. Ray Lankester be a Committee for the purpose of investigating the amount of Heat generated in the Blood, in the process of arterialization; that Dr. Gamgee be the Secretary, and that the sum of £15 be placed at their disposal for the purpose.

That Prof. Balfour, Dr. Cleghorn, and Mr. Robert Hutchison be a Committee for the purpose of taking observations on the effect of the denudation of timber on the Rainfall in North Britain; that Prof. Balfour be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That it is desirable to undertake a Geographical Exploration of the country of Moab, and that the following Members of the Association be a Committee for this purpose,—Sir R. I. Murchison, Bart., Rev. Dr. Ginsburg, Mr. Hepworth Dixon, Rev. Dr. Tristram, General Chesney, Rev. Professor Rawlinson, Mr. John A. Tinné; that the sum of £100 be placed at their disposal for the purpose.

That the Metric Committee be reappointed, such Committee to consist of Sir John Bowring, The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., The Right Hon. C. B. Adderley, M.P., Mr. Samuel Brown, Dr. Farr, Mr. Frank P. Fellowes, Professor Frankland, Mr. James Heywood, Professor Leone Levi, Professor W. A. Miller, Mr. C. W. Siemens, Professor A. W. Williamson, Dr. George Glover, Sir Joseph Whitworth, Bart., Mr. J. R. Napier, Mr. J. V. N. Bazalgette, and Sir W. Fairbairn, Bart.; that Professor Leone Levi be the Secretary, and that the sum of £25 be placed at their disposal for the purpose of being applied solely to scientific purposes, printing, and correspondence.

That Sir J. Lubbock, Bart., Mr. D. T. Ansted, Professor Corfield, Mr. J. Bailey Denton, Dr. J. H. Gilbert, Mr. R. B. Grantham, Mr. J. Thornhill Harrison, Mr. T. Hawksley, Mr. W. Hope, Lieut.-Colonel Leach, Professor Odling, Dr. A. Voelcker, and Professor A. W. Williamson, be a Committee for the purpose of carrying on the investigations of the Committee appointed last year on the Treatment and Utilization of Sewage; the expenses incurred being defrayed from the contributions, already received by the former Committee, from the towns.

That the Committee on the Treatment and Utilization of Sewage, appointed last year, having collected sums of money from several towns, it is resolved that the money collected by the said Committee, or the balance thereof, be paid over to the General Treasurer.

That no Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and that no money so raised shall be expended except in accordance with the rules of the Association.

Applications for Reports and Researches not involving Grants of Money.

That the Committee, consisting of Dr. Joule, Sir W. Thomson, Professor Tait, Professor Balfour Stewart, and Mr. J. Clerk Maxwell, be reappointed to effect a determination of the Mechanical Equivalent of Heat.

That Professor R. B. Clifton, Mr. Glaisher, Mr. Huggins, Dr. Matthiessen, Professor W. Hallows Miller, Dr. Balfour Stewart, Mr. G. Johnstone Stoney, Lieut.-Col. Strange, and Sir J. Whitworth, Bart., be a Committee for the purpose of reporting on Metric Standards, in reference to the communication from Professor Jacobi, appended hereto.

The Academy of Sciences of St. Petersburgh observing that the Standard Metric Weights and Measures of the various countries of Europe and of the United States, differ by sensible, though small, quantities from one another, express the opinion that the continuance of these errors would be highly prejudicial to science. They believe that the injurious effects could not be guarded against by private labours, however meritorious, and they have therefore recommended that an international commission be appointed by the countries interested to deal with this matter. They have decided to bring the subject before the Russian Government, and have appointed a Committee of their own Body, who have drawn up a careful Report containing valuable suggestions; and they have deputed Professor Jacobi to lay this Report before the British Association, and to request the Association to take action in reference to it.

That Mr. W. H. L. Russell be requested to continue his Report on recent progress in the theory of Elliptic and Hyperelliptic Functions.

That Dr. Matthiessen, Professor Abel, and Mr. David Forbes be a Committee for the purpose of continuing their researches on the Chemical Nature of Cast Iron.

That Dr. Bryce, Sir W. Thomson, Mr. D. Milne-Home, Mr. Macfarlane, and Mr. J. Brough be a Committee for the purpose of continuing investigations on Earthquakes in Scotland.

That Dr. Anton Dohrn, Professor Rolleston, and Mr. P. L. Sclater be a Committee for the purpose of promoting the foundation of Zoological Stations in different parts of the world, recognizing the foundation of a Zoological Station at Naples as a decided step in this direction; that Dr. Anton Dohrn be the Secretary.

That Mr. H. E. Dresser, Mr. J. E. Harting, Rev. H. Barnes, Rev. H. B. Tristram, and Professor Newton be reappointed for the purpose of continuing their investigations on the desirability of establishing "*a close time*" for the preservation of our indigenous animals; and that Mr. Dresser be the Secretary.

That the Committee appointed last year "to consider and report on the various plans proposed for legislating on the subject of Steam-Boiler Explosions with a view to their prevention," be requested to continue their labours; such Committee consisting of Sir Wm. Fairbairn, Bart., Sir Joseph

Whitworth, Bart., Mr. John Penn, Mr. F. J. Bramwell, Mr. Hugh Mason, Mr. Samuel Rigby, Mr. Thomas Schofield, Mr. Charles F. Beyer, Mr. T. Webster, Q.C., Mr. Lavington E. Fletcher.

That the Committee of Section D (Biology) be requested to draw up a statement of their views upon Physiological Experiments in their various bearings, and that this document be circulated among the Members of the Association.

That the said Committee be further requested to consider from time to time whether any steps can be taken by them, or by the Association, which will tend to reduce to its minimum, the suffering entailed by legitimate physiological inquiries; or any which will have the effect of employing the influence of this Association in the discouragement of experiments which are not clearly legitimate on live animals.

The following resolution subsequently passed by the Committee of Section D (Biology) was adopted:

That the following gentlemen be appointed a Committee for the purpose of carrying out the suggestion on the question of Physiological Experiments made by the General Committee,—Professor Rolleston, Professor Lawson, Professor Balfour, Dr. Gamgee, Professor M. Foster, Professor Humphry, Professor W. H. Flower, Professor Sanderson, Professor Macalister, and Professor Redfern; that Professor Rolleston be the Secretary, and that they be requested to report to the General Committee.

Involving Applications to Government.

That Sir R. I. Murchison, Bart., Sir Charles Lyell, Bart., Mr. Findlay, and Adm. Sir John D. Hay, be a Committee for the purpose of bringing to the notice of the Commissioners of the Admiralty the importance of revising the Survey of the West Coast of South America, with a view to ascertaining what changes have taken place in the levels since the recent great earthquakes on that coast; that Mr. Clements Markham be the Secretary.

That Prof. Jevons, Mr. R. Dudley Baxter, Sir John Bowring, Mr. J. T. Danson, Mr. James Heywood, Dr. W. B. Hodgson, and Professor Waley, be a Committee for the purpose of urging upon Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison; that Mr. Edmund Macrory be the Secretary.

Communications to be printed in extenso *in the Annual Report of the Association.*

That Professor Cayley's papers (1) "On In- and Circumscribed Triangles," and (2) "On the Correspondence of Lines and Points in Space," be printed *in extenso* in the Proceedings.

That the paper by Dr. Leith Adams on "Newly discovered Species of Elephants," be printed *in extenso* in the Report.

That the paper on "Ashton and Storey's Steampower Meter," be printed *in extenso* in the Transactions.

That owing to the great length and consequent cost of printing the tabular catalogue of Meteors presented by the Committee on Luminous Meteors, that part of their Report be not printed.

Resolutions referred to the Council for consideration and action if it seem desirable.

That the discontinuance of the maintenance of Kew Observatory by the British Association having been determined on, the President and Council be authorized to communicate with the President and Council of the Royal Society, and with the Government, so that the future use of the Buildings may in 1872 be placed at the disposal of the Royal Society, in case the Royal Society should desire it, under the same conditions as those Buildings are at present held by the British Association.

That the Council be empowered to cooperate with the Royal and Astronomical Societies, in the event of a new application being made to Government, to aid in the observation of the Solar Eclipse of December 1870.

That the Council be requested to take such steps as they deem wisest, in order to urge upon Government the importance of introducing Scientific Instruction into the Elementary Schools throughout the Country.

That the Council of the British Association be authorized, if it should appear to be desirable, to urge upon Her Majesty's Government the expediency of proposing to the Legislature a measure to insure the introduction of the metric system of weights and measures for international purposes.

That it is inexpedient that new Institutions for the teaching of Science, pure or applied, such as the proposed Engineering College for India, should be established by Government, until the Royal Commission now holding an inquiry into the Relation of the State to Scientific Instruction shall have issued their Report. That the Council of the British Association be requested to consider this opinion, and should they see fit, to urge it upon the attention of Her Majesty's Government.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Liverpool Meeting in September 1870. *The names of the Members who would be entitled to call on the General Treasurer for the respective Grants are prefixed.*

	£	s.	d.
Kew Observatory.			
The Council.—Maintaining the Establishment of Kew Observatory	600	0	0
Mathematics and Physics.			
*Brooke, Mr.—British Rainfall	50	0	0
*Thomson, Professor Sir W.—Underground Temperature	150	0	0
Carried forward	£800	0	0

* Reappointed.

	£	s.	d.
Brought forward	800	0	0
*Tait, Professor.—Thermal Conductivity of Iron and other Metals	20	0	0
*Thomson, Professor Sir W.—Tidal Observations	100	0	0
*Glaisher, Mr.—Luminous Meteors	30	0	0
Crossley, Mr.—Observation of Lunar Objects	20	0	0
Herschel, Sir J.—Recomputation of the Gaussian Constants for 1839	50	0	0
Stewart, Prof. B.—Standard Measures of Electrical Capacity	20	0	0
Thomson, Prof. Sir W.—Standard Electrical Potential Gauge	20	0	0
Hockin, Mr.—Standard Electrodynamometer	20	0	0
Chemistry.			
Williamson, Professor.—Reports of the Progress of Chemistry	100	0	0
Brown, Professor Crum.—Thermal Equivalents of the Oxides of Chlorine	25	0	0
Geology.			
*Lyell, Sir C., Bart.—Kent's-Cavern Exploration	150	0	0
*Duncan, Dr. P. M.—British Fossil Corals	25	0	0
*Symonds, Rev. W. S.—Sedimentary Deposits in the River Onny	10	0	0
*Mitchell, Mr. W. S.—Leaf-beds of the Lower Bagshot series	20	0	0
Thomson, Mr. James.—Sections of Fossil Corals	20	0	0
Scott, Mr. R. H.—Mesozoic Deposits of Omenak, North Greenland	50	0	0
Woodward, Mr. H.—British Fossil Crustacea	25	0	0
Busk, Mr.—Fossil Elephants of Malta	25	0	0
Biology.			
*Dr. Hooker.—Fossil Flora of Britain	25	0	0
*Sharpey, Dr.—Physiological Action of Methyl Compounds	25	0	0
*Sclater, Mr.—Record of the Progress of Zoology	100	0	0
*Foster, Professor M.—Heat Generated in the Arterialization of Blood	15	0	0
Balfour, Professor.—Effect of the Denudation of Timber on the Rainfall in North Britain	20	0	0
Geography.			
Murchison, Sir R., Bart.—Exploration of the Country of Moab	100	0	0
Statistics and Economic Science.			
*Bowring, Sir J.—Metrical Committee	25	0	0
Total	£1840	0	0

* Reappointed.

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	8
Skeleton Maps	20	0	0
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11

1842.

	£	s.	d.
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8

1843.

	£	s.	d.
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Cooperation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2

1844.

	£	s.	d.
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Cooperation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3

	£	s.	d.
Influence of Light on Plants......	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata ...	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas.....1842	100	0	0
Geographical Distributions of Marine Zoology.............1842	10	0	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Cooperation	16	16	8
Meteorological Instruments at Edinburgh........................	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells...	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds...............1843	2	0	7
Vitality of Seeds...............1844	7	0	0
Marine Zoology of Cornwall......	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£830	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Frossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1839................	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials...............	60	0	0
Researches in Asphyxia............	6	16	2
Examination of Fossil Shells......	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall......	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	3
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1839	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall ...	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants...............	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants...............	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves ...	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instrument, Azores	25	0	0
	£354	18	0

	£	s.	d.
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:— 1854......£ 75 0 0; 1855......£500 0 0	575	0	0
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4
1858.			
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	0
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2
1859.			
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1
1860.			
Maintaining the Establishment of Kew Observatory	500	0	0
Dredging near Belfast	16	6	0
Dredging in Dublin Bay	15	0	0

	£	s.	d.
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£1241	7	0

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee :— 1860 ...... £50 0 0; 1861 ...... £22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	1
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-East Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1855.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0

	£	s.	d.
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	0
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	20	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c. Leaf-Beds	30	0	0
Dredging, Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyle and Methyle series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl series	25	0	0
Mercury and Bile	25	0	0
Organic remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0

	£	s.	d.
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical nature of Cast iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

Extracts from Resolutions of the General Committee.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in Science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made, must (previously to the next meeting of the Association) forward to the General Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one meeting of the Association expire *a week before* the opening of the ensuing Meeting; nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, W. Spottiswoode, Esq., 50 Grosvenor Place, London, S.W., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed

to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

General Meetings.

On Wednesday Evening, September 14, at 8 P.M., in the Philharmonic Hall, Professor G. G. Stokes, D.C.L., F.R.S., President, resigned the office of President to Professor T. H. Huxley, LL.D., F.R.S., F.L.S., &c., who took the Chair, and delivered an Address, for which see page lxxiii.

On Thursday Evening, September 15, at 8 P.M., a Soirée took place in the Free Public Library and Museum.

On Friday Evening, September 16, at 8.30 P.M., in the Philharmonic Hall, Prof. Tyndall, LL.D., F.R.S., delivered a Discourse on "The Scientific Use of the Imagination."

On Saturday Evening, September 17, in the Music Hall, Lord Nelson Street, Sir John Lubbock, Bart., M.P., F.R.S., delivered a Discourse on "Savages" to the Operative Classes of Liverpool.

On Monday Evening, September 19, at 8.30 P.M., in the Philharmonic Hall, Professor W. J. Macquorn Rankine, LL.D., F.R.S., delivered a Discourse on "Stream-lines and Waves in connexion with Naval Architecture."

On Tuesday evening, September 20, at 8 P.M., a Soirée took place in the St. George's Hall.

On Wednesday, September 21, at 2.30 P.M., the concluding General Meeting took place, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Edinburgh*.

* The Meeting is appointed to take place on Wednesday, August 2, 1871.

ADDRESS

OF

THOMAS HENRY HUXLEY, LL.D., F.R.S.,

PRESIDENT.

My Lords, Ladies, and Gentlemen,

It has long been the custom for the newly installed President of the British Association for the Advancement of Science to take advantage of the elevation of the position in which the suffrages of his colleagues had, for the time, placed him, and, casting his eyes around the horizon of the scientific world, to report to them what could be seen from his watch-tower; in what directions the multitudinous divisions of the noble army of the improvers of natural knowledge were marching; what important strongholds of the great enemy of us all, Ignorance, had been recently captured; and, also, with due impartiality, to mark where the advanced posts of science had been driven in, or a long-continued siege had made no progress.

I propose to endeavour to follow this ancient precedent, in a manner suited to the limitations of my knowledge and of my capacity. I shall not presume to attempt a panoramic survey of the world of Science, nor even to give a sketch of what is doing in the one great province of Biology, with some portions of which my ordinary occupations render me familiar. But I shall endeavour to put before you the history of the rise and progress of a single biological doctrine; and I shall try to give some notion of the fruits, both intellectual and practical, which we owe, directly or indirectly, to the working out, by seven generations of patient and laborious investigators, of the thought which arose, more than two centuries ago, in the mind of a sagacious and observant Italian naturalist.

It is a matter of every day experience that it is difficult to prevent many articles of food from becoming covered with mould; that fruit, sound enough to all appearance, often contains grubs at the core; that meat, left to itself in the air, is apt to putrefy and swarm with maggots. Even ordinary water, if allowed to stand in an open vessel, sooner or later becomes turbid and full of living matter.

The philosophers of antiquity, interrogated as to the cause of these phenomena, were provided with a ready and a plausible answer. It did not enter their minds even to doubt that these low forms of life were generated in the matters in which they made their appearance. Lucretius, who had drunk deeper of the scientific spirit than any poet of ancient or modern times ex-

cept Goethe, intends to speak as a philosopher, rather than as a poet, when he writes that "with good reason the earth has gotten the name of mother, since all things are produced out of the earth. And many living creatures, even now, spring out of the earth, taking form by the rains and the heat of the sun"*. The axiom of ancient science, "that the corruption of one thing is the birth of another," had its popular embodiment in the notion that a seed dies before the young plant springs from it; a belief so widespread and so fixed, that Saint Paul appeals to it in one of the most splendid outbursts of his fervid eloquence:—

"Thou fool, that which thou sowest is not quickened, except it die"†.

The proposition that life may, and does, proceed from that which has no life, then, was held alike by the philosophers, the poets, and the people, of the most enlightened nations, eighteen hundred years ago; and it remained the accepted doctrine of learned and unlearned Europe, through the Middle Ages, down even to the seventeenth century.

It is commonly counted among the many merits of our great countryman, Harvey, that he was the first to declare the opposition of fact to venerable authority in this, as in other matters; but I can discover no justification for this widespread notion. After careful search through the 'Exercitationes de Generatione,' the most that appears clear to me is, that Harvey believed all animals and plants to spring from what he terms a "*primordium vegetale*," a phrase which may nowadays be rendered "a vegetative germ;" and this, he says, is "*oviforme*," or "egg-like;" not, he is careful to add, that it necessarily has the shape of an egg, but because it has the constitution and nature of one. That this "*primordium oviforme*" must needs, in all cases, proceed from a living parent is nowhere expressly maintained by Harvey, though such an opinion may be thought to be implied in one or two passages; while, on the other hand, he does, more than once, use language which is consistent only with a full belief in spontaneous or equivocal generation ‡. In fact, the main concern of Harvey's wonderful little treatise is not with generation, in the physiological sense, at all, but with development; and his great object is the establishment of the doctrine of epigenesis.

The first distinct enunciation of the hypothesis that all living matter has sprung from preexisting living matter, came from a contemporary, though a junior, of Harvey, a native of that country, fertile in men great in all departments of human activity, which was to intellectual Europe in the six-

* It is thus that Mr. Munro renders:—

> "Linquitur, ut merito maternum nomen adepta
> Terra sit, e terra quoniam sunt cuncta creata.
> Multaque nunc etiam exsistunt animalia terris
> Imbribus et calido solis concreta vapore."
>
> De Rerum Natura, lib. v. 793–796.

But would not the meaning of the last line be better rendered "Developed in rain-water and in the warm vapours raised by the sun?"

† 1 Corinthians, xv. 36.

‡ See the following passage in Exercitatio I.:—"Item *sponte nascentia* dicuntur; non quod ex *putredine* oriunda sint: sed quôd casu, naturæ sponte, et æquivocâ (ut aiunt) generatione, à parentibus sui dissimilibus proveniant." Again, in 'De Uteri Membranis':—"In cunctorum viventium generatione (sicut diximus) hoc solenne est, ut ortum ducunt a *primordio* aliquo, quod tum materiam tum efficiendi potestatem in se habet; sitque adeo id, ex quo et a quo quicquid nascitur, ortum suum ducat. Tale primordium in animalibus (*sive ab aliis generantibus proveniant, sive sponte, aut ex putredine nascentur*) est humor in tunicâ aliquâ aut putamine conclusus." Compare also what Redi has to say respecting Harvey's opinions, 'Esperienze,' p. 11.

teenth and seventeenth centuries what Germany is in the nineteenth. It was in Italy, and from Italian teachers, that Harvey received the most important part of his scientific education. And it was a student trained in the same schools, Francesco Redi—a man of the widest knowledge and most versatile abilities, distinguished alike as scholar, poet, physician, and naturalist,—who, just two hundred and two years ago, published his 'Esperienze intorno alla Generazione degl' Insetti,' and gave to the world the idea, the growth of which it is my purpose to trace. Redi's book went through five editions in twenty years; and the extreme simplicity of his experiments, and the clearness of his arguments, gained for his views, and for their consequences, almost universal acceptance.

Redi did not trouble himself much with speculative considerations, but attacked particular cases of what was supposed to be "spontaneous generation" experimentally. Here are dead animals, or pieces of meat, says he; I expose them to the air in hot weather, and in a few days they swarm with maggots. You tell me that these are generated in the dead flesh; but if I put similar bodies, while quite fresh, into a jar, and tie some fine gauze over the top of the jar, not a maggot makes its appearance, while the dead substances, nevertheless, putrefy just in the same way as before. It is obvious, therefore, that the maggots are not generated by the corruption of the meat; and that the cause of their formation must be a something which is kept away by gauze. But gauze will not keep away aëriform bodies, or fluids. This something must, therefore, exist in the form of solid particles too big to get through the gauze. Nor is one long left in doubt what these solid particles are; for the blowflies, attracted by the odour of the meat, swarm round the vessel and, urged by a powerful but, in this case, misleading instinct, lay eggs, out of which maggots are immediately hatched, upon the gauze. The conclusion, therefore, is unavoidable; the maggots are not generated by the meat, but the eggs which give rise to them are brought through the air by the flies.

These experiments seem almost childishly simple, and one wonders how it was that no one ever thought of them before. Simple as they are, however, they are worthy of the most careful study, for every piece of experimental work since done, in regard to this subject, has been shaped upon the model furnished by the Italian philosopher. As the results of his experiments were the same, however varied the nature of the materials he used, it is not wonderful that there arose in Redi's mind a presumption, that in all such cases of the seeming production of life from dead matter, the real explanation was the introduction of living germs from without into that dead matter*. And thus the hypothesis that living matter always arises by the

* "Pure contentandomi sempre in questa ed in ciascuna altra cosa, da ciascuno più savio, là dove io difettuosamente parlassi, esser corretto; non tacero, che per molte osservazioni molti volti da me fatte, mi sento inclinato a credere che la terra, da quelle prime piante, e da quei primi animali in poi, che ella nei primi giorni del mondo produsse per comandemento del sovrano ed omnipotente Fattore, non abbia mai più prodotto da se medesima nè erba nè albero, nè animale alcuno perfetto o imperfetto che ei se fosse; e che tutto quello, che ne' tempi trapassati è nato e che ora nascere in lei, o da lei veggiamo, venga tutto dalla semenza reale e vera delle piante, e degli animali stessi, i quali col mezzo del proprio seme la loro spezie conservano. E se bene tutto giorno scorghiamo da' cadaveri degli animali, e da tutte quante le maniere dell' erbe, e de' fiori, e dei frutti imputriditi, e corrotti nascere vermi infiniti—

> Nonne vides quæcunque mora, fluidoque calore
> Corpora tabescunt in parva animalia verti—

Io mi sento, dico, inclinato a credere che tutti quei vermi si generino dal seme

agency of preexisting living matter, took definite shape; and had, henceforward, a right to be considered and a claim to be refuted, in each particular case, before the production of living matter in any other way could be admitted by careful reasoners. It will be necessary for me to refer to this hypothesis so frequently, that, to save circumlocution, I shall call it the hypothesis of *Biogenesis*; and I shall term the contrary doctrine—that living matter may be produced by not living matter—the hypothesis of *Abiogenesis.*

In the seventeenth century, as I have said, the latter was the dominant view, sanctioned alike by antiquity and by authority; and it is interesting to observe that Redi did not escape the customary tax upon a discoverer of having to defend himself against the charge of impugning the authority of the Scriptures *; for his adversaries declared that the generation of bees from the carcass of a dead lion is affirmed, in the book of Judges, to have been the origin of the famous riddle with which Samson perplexed the Philistines:

> "Out of the eater came forth meat,
> And out of the strong came forth sweetness."

Against all odds, however, Redi, strong with the strength of demonstrable fact, did splendid battle for Biogenesis; but it is remarkable that he held the doctrine in a sense which, if he had lived in these times, would have infallibly caused him to be classed among the defenders of "spontaneous generation." "Omne vivum ex vivo," "no life without antecedent life," aphoristically sums up Redi's doctrine; but he went no further. It is most remarkable evidence of the philosophic caution and impartiality of his mind, that, although he had speculatively anticipated the manner in which grubs really are deposited in fruits and in the galls of plants, he deliberately admits that the evidence is insufficient to bear him out; and he therefore prefers the supposition that they are generated by a modification of the living substance of the plants themselves. Indeed, he regards these vegetable growths as organs, by means of which the plant gives rise to an animal, and looks upon this production of specific animals as the final cause of the galls and of, at any rate some, fruits. And he proposes to explain the occurrence of parasites within the animal body in the same way †.

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paterno; e che le carni, e l'erbe, e l'altre cose tutte putrefatte, o putrefattibili non facciano altra parte, nè abbiano altro ufizio nella generazione degl' insetti, se non d'apprestare un luogo o un nido proporzionato, in cui dagli animali nel tempo della figliatura sieno portati, e partoriti i vermi, o l'uova o l'altre semenze dei vermi, i quali tosto che nati sono, trovano in esso nido un sufficiente alimento abilissimo per nutricarsi: e se in quello non son portate dalle madri queste suddette semenze, niente mai, e replicatamente niente, vi s'ingegneri e nasca."—Redi, *Esperienze*, pp. 14–16.

* "Molti, e molti altri ancora vi potrei annoverare, se non fossi chiamato a rispondere alle rampogne di alcuni, che bruscamente mi rammentano ciò, che si legge nel capitolo quattordicesimo del sacrosanto Libro de' giudici. . . . ."—Redi, *l. c.* p. 45.

† The passage (Esperienze, p. 129) is worth quoting in full:—

"Se dovessi palesarvi il mio sentimento crederei che i frutti, i legumi, gli alberi e le foglie, in due maniere inverminassero. Una, perchè venendo i bachi per di fuora, e cercando l'alimento, col rodere ci aprono la strada, ed arrivano alla più interna midolla de' frutti e de' legni. L'altra maniera si è, che io per me stimerei, che non fosse gran fatto disdicevole il credere, che quell' anima o quella virtù, la quale genera i fiori ed i frutti nelle piante viventi, sia quella stessa che generi ancora i bachi di esse piante. E chi sà forse, che molti frutti degli alberi non sieno prodotti, non per un fine primario e principale, ma bensì per un uffizio secondario e servile, destinato alla generazione di que' vermi, servendo a loro in vece di matrice, in cui dimorino un prefisso e determinato tempo; il quale arrivato escan fuora a godere il sole.

"Io m' immagino, che questo mio pensiero non vi parrà totalmente un paradosso; mentre

It is of great importance to apprehend Redi's position rightly; for the lines of thought he laid down for us are those upon which naturalists have been working ever since. Clearly, he held *Biogenesis* as against *Abiogenesis*; and I shall immediately proceed, in the first place, to inquire how far subsequent investigation has borne him out in so doing.

But Redi also thought that there were two modes of Biogenesis. By the one method, which is that of common and ordinary occurrence, the living parent gives rise to offspring which passes through the same cycle of changes as itself—like gives rise to like; and this has been termed *Homogenesis*. By the other mode, the living parent was supposed to give rise to offspring which passed through a totally different series of states from those exhibited by the parent, and did not return into the cycle of the parent: this is what ought to be called *Heterogenesis*, the offspring being altogether, and permanently, unlike the parent. The term Heterogenesis, however, has unfortunately been used in a different sense, and M. Milne-Edwards has therefore substituted for it *Xenogenesis*, which means the generation of something foreign. After discussing Redi's hypothesis of universal Biogenesis, then, I shall go on to ask how far the growth of science justifies his other hypothesis of Xenogenesis.

The progress of the hypothesis of Biogenesis was triumphant and unchecked for nearly a century. The application of the microscope to anatomy in the hands of Grew, Leeuwenhoek, Swammerdam, Lyonet, Vallisnieri, Reaumur, and other illustrious investigators of nature of that day, displayed such a complexity of organization in the lowest and minutest forms, and everywhere revealed such a prodigality of provision for their multiplication by germs of one sort or another, that the hypothesis of Abiogenesis began to appear not only untrue, but absurd; and in the middle of the eighteenth century, when Needham and Buffon took up the question, it was almost universally discredited*.

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farete riflessione a quelle tante sorte di galle, di gallozzole, di coccole, di ricci, di calici, di cornetti e di lappole, che son produtte dalle querce, dalle farnie, da' cerri, da' sugheri, da' lecci e da altri simili alberi da ghianda; imperciocchè in quelle gallozzole, e particolarmente nelle più grosse, che si chiamano coronati, ne' ricci capelluti, che ciuffoli da' nostri contadini son detti; nei ricci legnosi del cerro, ne' ricci stellati della quercia, nelle galluzze della foglia del leccio si vede evidentissimamente, che la prima e principale intenzione della natura è formare dentro di quelle un animale volante; vedendosi nel centro della gallozzola un uovo, che col crescere e col maturarsi di essa gallozzola va crescendo e maturando anch' egli, e cresce altresì a suo tempo quel verme, che nell' uovo si racchiude; il qual verme, quando la gallozzola è finita di maturare e che è venuto il termine destinato al suo nascimento, diventa, di verme che era, una mosca. . . . . Io vi confesso ingenuamente, che prima d'aver fatte queste mie esperienze intorno alla generazione degl' insetti mi dava a credere, o per dir meglio sospettava, che forse la gallozzola nascesse, perchè arrivando la mosca nel tempo della primavera, e facendo una piccolissima fessura ne' rami più teneri della quercia, in quella fessura nascondesse uno de suoi semi, il quale fosse cagione che sbocciasse fuora la gallozzola; e che mai non si vedessero galle o gallozzole o ricci o cornetti o calici o coccole, se non in que' rami, ne' quali le mosche avessero depositate le loro semenze; e mi dava ad intendere, che le gallozzole fossero una malattia cagionata nelle querce dalle punture delle mosche, in quella guisa stessa che dalle punture d'altri animaletti simiglievoli veggiamo crescere de' tumori ne' corpi degli animali."

* Needham, writing in 1750, says:—

"Les naturalistes modernes s'accordent unanimement à établir, comme une vérité certaine, que toute plante vient de sa sémence spécifique, tout animal d'un œuf ou de quelque chose d'analogue préexistant dans la plante, ou dans l'animal de même espèce qui l a produit."—*Nouvelles Observations*, p. 169.

"Les naturalistes ont généralement cru que les animaux microscopiques étaient engendrés par des œufs transportés dans l'air, ou déposés dans des eaux dormantes par des insectes volans."—*Ibid.* p. 176.

But the skill of the microscope-makers of the eighteenth century soon reached its limit. A microscope magnifying 400 diameters was a *chef-d'œuvre* of the opticians of that day, and, at the same time, by no means trustworthy. But a magnifying-power of 400 diameters, even when definition reaches the exquisite perfection of our modern achromatic lenses, hardly suffices for the mere discernment of the smallest forms of life. A speck, only $\frac{1}{25}$ of an inch in diameter, has, at 10 inches from the eye, the same apparent size as an object $\frac{1}{10000}$ of an inch in diameter, when magnified 400 times; but forms of living matter abound the diameter of which is not more than $\frac{1}{100000}$ of an inch. A filtered infusion of hay, allowed to stand for two days, will swarm with living things, among which any which reaches the diameter of a human red blood-corpuscle, or about $\frac{1}{3200}$ of an inch, is a giant. It is only by bearing these facts in mind that we can deal fairly with the remarkable statements and speculations put forward by Buffon and Needham in the middle of the eighteenth century.

When a portion of any animal or vegetable body is infused in water, it gradually softens and disintegrates; and, as it does so, the water is found to swarm with minute active creatures, the so-called Infusorial Animalcules, none of which can be seen, except by the aid of the microscope; while a large proportion belong to the category of smallest things of which I have spoken, and which must have all looked like mere dots and lines under the ordinary microscopes of the eighteenth century.

Led by various theoretical considerations which I cannot now discuss, but which looked promising enough in the lights of that day, Buffon and Needham doubted the applicability of Redi's hypothesis to the infusorial animalcules, and Needham very properly endeavoured to put the question to an experimental test. He said to himself, if these infusorial animalcules come from germs, their germs must exist either in the substance infused, or in the water with which the infusion is made, or in the superjacent air. Now the vitality of all germs is destroyed by heat. Therefore, if I boil the infusion, cork it up carefully, cementing the cork over with mastic, and then heat the whole vessel by heaping hot ashes over it, I must needs kill whatever germs are present. Consequently, if Redi's hypothesis hold good, when the infusion is taken away and allowed to cool, no animalcules ought to be developed in it; whereas, if the animalcules are not dependent on preexisting germs, but are generated from the infused substance, they ought, by-and-by, to make their appearance. Needham found that, under the circumstances in which he made his experiments, animalcules always did arise in the infusions, when a sufficient time had elapsed to allow for their development.

In much of his work Needham was associated with Buffon, and the results of their experiments fitted in admirably with the great French naturalist's hypothesis of "organic molecules," according to which, life is the indefeasible property of certain indestructible molecules of matter, which exist in all living things, and have inherent activities by which they are distinguished from not living matter. Each individual living organism is formed by their temporary combination. They stand to it in the relation of the particles of water to a cascade, or a whirlpool; or to a mould, into which the water is poured. The form of the organism is thus determined by the reaction between external conditions and the inherent activities of the organic molecules of which it is composed; and, as the stoppage of a whirlpool destroys nothing but a form, and leaves the molecules of the water with all their inherent activities intact, so, what we call the death and putrefaction of an animal, or of a plant, is merely the breaking up of the form, or manner of

association, of its constituent organic molecules, which are then set free as infusorial animalcules.

It will be perceived that this doctrine is by no means identical with *Abiogenesis*, with which it is often confounded. On this hypothesis, a piece of beef, or a handful of hay, is dead only in a limited sense. The beef is dead ox, and the hay is dead grass; but the "organic molecules" of the beef or the hay are not dead, but are ready to manifest their vitality as soon as the bovine or herbaceous shrouds in which they are imprisoned are rent by the macerating action of water. The hypothesis therefore must be classified under Xenogenesis, rather than under Abiogenesis. Such as it was, I think it will appear, to those who will be just enough to remember that it was propounded before the birth of modern chemistry and of the modern optical arts, to be a most ingenious and suggestive speculation.

But the great tragedy of Science—the slaying of a beautiful hypothesis by an ugly fact—which is so constantly being enacted under the eyes of philosophers, was played, almost immediately, for the benefit of Buffon and Needham.

Once more, an Italian, the Abbé Spallanzani, a worthy successor and representative of Redi in his acuteness, his ingenuity, and his learning, subjected the experiments and the conclusions of Needham to a searching criticism. It might be true that Needham's experiments yielded results such as he had described, but did they bear out his arguments? Was it not possible, in the first place, that he had not completely excluded the air by his corks and mastic? And was it not possible, in the second place, that he had not sufficiently heated his infusions and the superjacent air? Spallanzani joined issue with the English naturalist on both these pleas; and he showed that if, in the first place, the glass vessels in which the infusions were contained were hermetically sealed by fusing their necks; and if, in the second place, they were exposed to the temperature of boiling water for three-quarters of an hour *, no animalcules ever made their appearance within them. It must be admitted that the experiments and arguments of Spallanzani furnish a complete and a crushing reply to those of Needham. But we all too often forget that it is one thing to refute a proposition, and another to prove the truth of a doctrine which implicitly, or explicitly, contradicts that proposition; and the advance of science soon showed that though Needham might be quite wrong, it did not follow that Spallanzani was quite right.

Modern Chemistry, the birth of the latter half of the eighteenth century, grew apace, and soon found herself face to face with the great problems which Biology had vainly tried to attack without her help. The discovery of oxygen led to the laying of the foundations of a scientific theory of respiration, and to an examination of the marvellous interactions of organic substances with oxygen. The presence of free oxygen appeared to be one of the conditions of the existence of life, and of those singular changes in organic matters which are known as fermentation and putrefaction. The question of the generation of the infusory animalcules thus passed into a new phase. For what might not have happened to the organic matter of the infusions, or to the oxygen of the air, in Spallanzani's experiments? What security was there that the development of life which ought to have taken place had not been checked, or prevented, by these changes?

The battle had to be fought again. It was needful to repeat the experiments under conditions which would make sure that neither the oxygen

* See Spallanzani, 'Opere,' vi. pp. 42 & 51.

of the air, nor the composition of the organic matter, was altered, in such a manner as to interfere with the existence of life.

Schulze and Schwann took up the question from this point of view in 1836 and 1837. The passage of air through red-hot glass tubes, or through strong sulphuric acid, does not alter the proportion of its oxygen, while it must needs arrest, or destroy, any organic matter which may be contained in the air. These experimenters, therefore, contrived arrangements by which the only air which should come into contact with a boiled infusion should be such as had either passed through red-hot tubes, or through strong sulphuric acid. The result which they obtained was that an infusion so treated developed no living things, while if the same infusion was afterwards exposed to the air such things appeared rapidly and abundantly. The accuracy of these experiments has been alternately denied and affirmed. Supposing them to be accepted, however, all that they really proved was, that the treatment to which the air was subjected destroyed *something* that was essential to the development of life in the infusion. This "something" might be gaseous, fluid, or solid; that it consisted of germs remained only an hypothesis of greater or less probability.

Contemporaneously with these investigations a remarkable discovery was made by Cagniard de la Tour. He found that common yeast is composed of a vast accumulation of minute plants. The fermentation of must, or of wort, in the fabrication of wine and of beer, is always accompanied by the rapid growth and multiplication of these *Torulæ*. Thus fermentation, in so far as it was accompanied by the development of microscopical organisms in enormous numbers, became assimilated to the decomposition of an infusion of ordinary animal or vegetable matter; and it was an obvious suggestion that the organisms were, in some way or other, the causes both of fermentation and of putrefaction. The chemists, with Berzelius and Liebig at their head, at first laughed this idea to scorn; but in 1843, a man then very young, who has since performed the unexampled feat of attaining to high eminence alike in Mathematics, Physics, and Physiology,—I speak of the illustrious Helmholtz—reduced the matter to the test of experiment by a method alike elegant and conclusive. Helmholtz separated a putrefying, or a fermenting liquid, from one which was simply putrescible, or fermentable, by a membrane, which allowed the fluids to pass through and become intermixed, but stopped the passage of solids. The result was, that while the putrescible, or the fermentable, liquids became impregnated with the results of the putrescence, or fermentation, which was going on on the other side of the membrane, they neither putrefied (in the ordinary way) nor fermented; nor were any of the organisms which abounded in the fermenting, or putrefying, liquid generated in them. Therefore, the cause of the development of these organisms must lie in something which cannot pass through membrane; and as Helmholtz's investigations were long antecedent to Graham's researches upon colloids, his natural conclusion was, that the agent thus intercepted must be a solid material. In point of fact, Helmholtz's experiments narrowed the issue to this: that which excites fermentation and putrefaction, and at the same time gives rise to living forms in a fermentable, or putrescible, fluid, is not a gas and is not a diffusible fluid; therefore it is either a colloid, or it is matter divided into very minute solid particles.

The researches of Schroeder and Dusch in 1854, and of Schroeder alone in 1859, cleared up this point by experiments which are simply refinements upon those of Redi. A lump of cotton-wool is, physically speaking, a pile of many thicknesses of a very fine gauze, the fineness of the meshes of which

depends upon the closeness of the compression of the wool. Now, Schroeder and Dusch found, that, in the case of all the putrefiable materials which they used (except milk and yolk of egg), an infusion boiled, and then allowed to come into contact with no air but such as had been filtered through cotton-wool, neither putrefied nor fermented, nor developed living forms. It is hard to imagine what the fine sieve formed by the cotton-wool could have stopped except minute solid particles. Still the evidence was incomplete until it had been positively shown, first, that ordinary air does contain such particles; and, secondly, that filtration through cotton-wool arrests these particles and allows only physically pure air to pass. This demonstration has been furnished within the last year by the remarkable experiments of Professor Tyndall. It has been a common objection of Abiogenists that, if the doctrine of Biogeny is true, the air must be thick with germs; and they regard this as the height of absurdity. But Nature occasionally is exceedingly unreasonable, and Professor Tyndall has proved that this particular absurdity may nevertheless be a reality. He has demonstrated that ordinary air is no better than a sort of stirabout of excessively minute solid particles; that these particles are almost wholly destructible by heat; and that they are strained off, and the air rendered optically pure, by being passed through cotton-wool.

But it remains yet in the order of logic, though not of history, to show that, among these solid destructible particles, there really do exist germs capable of giving rise to the development of living forms in suitable menstrua. This piece of work was done by M. Pasteur in those beautiful researches which will ever render his name famous; and which, in spite of all attacks upon them, appear to me now, as they did seven years ago*, to be models of accurate experimentation and logical reasoning. He strained air through cotton-wool, and found, as Schroeder and Dusch had done, that it contained nothing competent to give rise to the development of life in fluids highly fitted for that purpose. But the important further links in the chain of evidence added by Pasteur are three. In the first place, he subjected to microscopic examination the cotton-wool which had served as strainer, and found that sundry bodies, clearly recognizable as germs, were among the solid particles strained off. Secondly, he proved that these germs were competent to give rise to living forms by simply sowing them in a solution fitted for their development. And, thirdly, he showed, that the incapacity of air strained through cotton-wool to give rise to life, was not due to any occult change effected in constituents of the air by the wool, by proving that the cotton-wool might be dispensed with altogether, and perfectly free access left between the exterior air and that in the experimental flask. If the neck of the flask is drawn out into a tube and bent downwards; and if, after the contained fluid has been carefully boiled, the tube is heated sufficiently to destroy any germs which may be present in the air which enters as the fluid cools, the apparatus may be left to itself for any time, and no life will appear in the fluid. The reason is plain. Although there is free communication between the atmosphere laden with germs and the germless air in the flask, contact between the two takes place only in the tube; and as the germs cannot fall upwards, and there are no currents, they never reach the interior of the flask. But if the tube be broken short off where it proceeds from the flask, and free access be thus given to germs falling vertically out of the air,

* "Lectures to Working Men on the Causes of the Phenomena of Organic Nature," 1863.

the fluid which has remained clear and desert for months, becomes, in a few days, turbid and full of life.

These experiments have been repeated over and over again by independent observers with entire success; and there is one very simple mode of seeing the facts for one's self, which I may as well describe.

Prepare a solution (much used by M. Pasteur, and often called "Pasteur's solution") composed of water with tartrate of ammonia, sugar, and yeast-ash dissolved therein*. Divide it into three portions in as many flasks; boil all three for a quarter of an hour; and, while the steam is passing out, stop the neck of one with a large plug of cotton-wool, so that this also may be thoroughly steamed. Now set the flasks aside to cool, and when their contents are cold, add to one of the open ones a drop of filtered infusion of hay which has stood for twenty-four hours, and is consequently full of the active and excessively minute organisms known as *Bacteria*. In a couple of days of ordinary warm weather, the contents of this flask will be milky, from the enormous multiplication of *Bacteria*. The other flask, open and exposed to the air, will, sooner or later, become milky with *Bacteria*, and patches of mould may appear in it; while the liquid in the flask, the neck of which is plugged with cotton-wool, will remain clear for an indefinite time. I have sought in vain for any explanation of these facts, except the obvious one, that the air contains germs, competent to give rise to *Bacteria*, such as those with which the first solution has been knowingly and purposely inoculated, and to the mould *Fungi*. And I have not yet been able to meet with any advocate of Abiogenesis who seriously maintains that the atoms of sugar, tartrate of ammonia, yeast-ash, and water, under no influence but that of free access of air and the ordinary temperature, rearrange themselves and give rise to the protoplasm of *Bacterium*. But the alternative is to admit that these *Bacteria* arise from germs in the air; and if they are thus propagated, the burden of proof, that other like forms are generated in a different manner, must rest with the assertor of that proposition.

To sum up the effect of this long chain of evidence:—

It is demonstrable, that a fluid eminently fit for the development of the lowest forms of life, but which contains neither germs nor any protein compound, gives rise to living things in great abundance if it is exposed to ordinary air; while no such development takes place if the air with which it is in contact is mechanically freed from the solid particles, which ordinarily float in it and which may be made visible by appropriate means.

It is demonstrable, that the great majority of these particles are destructible by heat, and that some of them are germs, or living particles, capable of giving rise to the same forms of life as those which appear when the fluid is exposed to unpurified air.

It is demonstrable, that inoculation of the experimental fluid with a drop of liquid known to contain living particles gives rise to the same phenomena as exposure to unpurified air.

And it is further certain that these living particles are so minute that the assumption of their suspension in ordinary air presents not the slightest difficulty. On the contrary, considering their lightness and the wide diffusion of the organisms which produce them, it is impossible to conceive that they should not be suspended in the atmosphere in myriads.

Thus the evidence, direct and indirect, in favour of *Biogenesis* for all known forms of life must, I think, be admitted to be of great weight.

* Infusion of hay, treated in the same way, yields similar results; but as it contains organic matter, the argument which follows cannot be based upon it.

On the other side, the sole assertions worthy of attention are, that hermetically sealed fluids, which have been exposed to great and long-continued heat, have sometimes exhibited living forms of low organization when they have been opened.

The first reply that suggests itself is the probability that there must be some error about these experiments, because they are performed on an enormous scale every day, with quite contrary results. Meat, fruits, vegetables, the very materials of the most fermentable and putrescible infusions, are preserved to the extent, I suppose I may say, of thousands of tons every year, by a method which is a mere application of Spallanzani's experiment. The matters to be preserved are well boiled in a tin case provided with a small hole, and this hole is soldered up when all the air in the case has been replaced by steam. By this method they may be kept for years, without putrefying, fermenting, or getting mouldy. Now this is not because oxygen is excluded, inasmuch as it is now proved that free oxygen is not necessary for either fermentation or putrefaction. It is not because the tins are exhausted of air, for *Vibriones* and *Bacteria* live, as Pasteur has shown, without air or free oxygen. It is not because the boiled meats or vegetables are not putrescible or fermentable, as those who have had the misfortune to be in a ship supplied with unskilfully closed tins well know. What is it, therefore, but the exclusion of germs? I think that Abiogenists are bound to answer this question before they ask us to consider new experiments of precisely the same order.

And in the next place, if the results of the experiments I refer to are really trustworthy, it by no means follows that abiogenesis has taken place. The resistance of living matter to heat is known to vary within considerable limits, and to depend, to some extent, upon the chemical and physical qualities of the surrounding medium. But if, in the present state of science, the alternative is offered us, either germs can stand a greater heat than has been supposed, or the molecules of dead matter, for no valid or intelligible reason that is assigned, are able to rearrange themselves into living bodies, exactly such as can be demonstrated to be frequently produced in another way, I cannot understand how choice can be, even for a moment, doubtful.

But though I cannot express this conviction of mine too strongly, I must carefully guard myself against the supposition that I intend to suggest that no such thing as abiogenesis ever has taken place in the past, or ever will take place in the future. With organic chemistry, molecular physics, and physiology yet in their infancy, and every day making prodigious strides, I think it would be the height of presumption for any man to say that the conditions under which matter assumes the properties we call "vital" may not, some day, be artificially brought together. All I feel justified in affirming is, that I see no reason for believing that the feat has been performed yet.

And, looking back through the prodigious vista of the past, I find no record of the commencement of life, and therefore I am devoid of any means of forming a definite conclusion as to the conditions of its appearance. Belief, in the scientific sense of the word, is a serious matter, and needs strong foundations. To say, therefore, in the admitted absence of evidence, that I have any belief as to the mode in which the existing forms of life have originated, would be using words in a wrong sense. But expectation is permissible where belief is not; and if it were given me to look beyond the abyss of geologically recorded time to the still more remote period when the earth was passing through physical and chemical conditions, which it can no

more see again than a man can recall his infancy, I should expect to be a witness of the evolution of living protoplasm from not living matter. I should expect to see it appear under forms of great simplicity, endowed, like existing Fungi, with the power of determining the formation of new protoplasm from such matters as ammonium carbonates, oxalates and tartrates, alkaline and earthy phosphates, and water, without the aid of light. That is the expectation to which analogical reasoning leads me; but I beg you once more to recollect that I have no right to call my opinion any thing but an act of philosophical faith.

So much for the history of the progress of Redi's great doctrine of Biogenesis, which appears to me, with the limitations I have expressed, to be victorious along the whole line at the present day.

As regards the second problem offered to us by Redi, whether Xenogenesis obtains, side by side with Homogenesis; whether, that is, there exist not only the ordinary living things, giving rise to offspring which run through the same cycle as themselves, but also others, producing offspring which are of a totally different character from themselves, the researches of two centuries have led to a different result. That the grubs found in galls are no product of the plants on which the galls grow, but are the result of the introduction of the eggs of insects into the substance of these plants, was made out by Vallisnieri, Reaumur, and others, before the end of the first half of the eighteenth century. The tapeworms, bladderworms, and flukes continued to be a stronghold of the advocates of Xenogenesis for a much longer period. Indeed it is only within the last thirty years that the splendid patience of Von Siebold, Van Beneden, Leuckart, Küchenmeister, and other helminthologists has succeeded in tracing every such parasite, often through the strangest wanderings and metamorphoses, to an egg derived from a parent, actually or potentially like itself; and the tendency of inquiries elsewhere has all been in the same direction. A plant may throw off bulbs, but these, sooner or later, give rise to seeds or spores, which develope into the original form. A polype may give rise to Medusæ, or a pluteus to an Echinoderm, but the Medusa and the Echinoderm give rise to eggs which produce polypes or plutei, and they are therefore only stages in the cycle of life of the species.

But if we turn to pathology it offers us some remarkable approximations to true Xenogenesis.

As I have already mentioned, it has been known since the time of Vallisnieri and of Reaumur, that galls in plants, and tumours in cattle, are caused by insects, which lay their eggs in those parts of the animal or vegetable frame of which these morbid structures are outgrowths. Again, it is a matter of familiar experience to everybody that mere pressure on the skin will give rise to a corn. Now the gall, the tumour, and the corn are parts of the living body, which have become, to a certain degree, independent and distinct organisms. Under the influence of certain external conditions, elements of the body, which should have developed in due subordination to its general plan, set up for themselves and apply the nourishment which they receive to their own purposes.

From such innocent productions as corns and warts, there are all gradations to the serious tumours which, by their mere size and the mechanical obstruction they cause, destroy the organism out of which they are developed; while, finally, in those terrible structures known as cancers, the abnormal growth has acquired powers of reproduction and multiplication, and is only morphologically distinguishable from the parasitic worm, the life of which is neither more, nor less, closely bound up with that of the infested organism.

If there were a kind of diseased structure, the histological elements of which were capable of maintaining a separate and independent existence out of the body, it seems to me that the shadowy boundary between morbid growth and Xenogenesis would be effaced. And I am inclined to think that the progress of discovery has almost brought us to this point already. I have been favoured by Mr. Simon with an early copy of the last published of the valuable "Reports on the Public Health," which, in his capacity of their Medical Officer, he annually presents to the Lords of the Privy Council. The Appendix to this Report contains an introductory essay "On the Intimate Pathology of Contagion," by Dr. Burdon Sanderson, which is one of the clearest, most comprehensive, and well-reasoned discussions of a great question which has come under my notice for a long time. I refer you to it for details and for the authorities for the statements I am about to make.

You are familiar with what happens in vaccination. A minute cut is made in the skin, and an infinitesimal quantity of vaccine matter is inserted into the wound. Within a certain time, a vesicle appears in the place of the wound, and the fluid which distends this vesicle is vaccine matter, in quantity a hundred- or a thousandfold that which was originally inserted. Now what has taken place in the course of this operation? Has the vaccine matter by its irritative property produced a mere blister, the fluid of which has the same irritative property? Or does the vaccine matter contain living particles, which have grown and multiplied where they have been planted? The observations of M. Chauveau, extended and confirmed by Dr. Sanderson himself, appear to leave no doubt upon this head. Experiments, similar in principle to those of Helmholtz on fermentation and putrefaction, have proved that the active element in the vaccine lymph is non-diffusible, and consists of minute particles not exceeding $\frac{1}{20000}$ of an inch in diameter, which are made visible in the lymph by the microscope. Similar experiments have proved that two of the most destructive of epizootic diseases, sheep-pox and glanders, are also dependent for their existence and their propagation upon extremely small living solid particles, to which the title of *microzymes* is applied. An animal suffering under either of these terrible diseases is a source of infection and contagion to others, for precisely the same reason as a tub of fermenting beer is capable of propagating its fermentation by "infection," or "contagion," to fresh wort. In both cases it is the solid living particles which are efficient; the liquid in which they float, and at the expense of which they live, being altogether passive.

Now arises the question, are these microzymes the results of *Homogenesis*, or of *Xenogenesis*; are they capable, like the *Torulæ* of yeast, of arising only by the development of preexisting germs; or may they be, like the constituents of a nut-gall, the results of a modification and individualization of the tissues of the body in which they are found, resulting from the operation of certain conditions? Are they parasites in the zoological sense, or are they merely what Virchow has called "heterologous growths"? It is obvious that this question has the most profound importance, whether we look at it from a practical or from a theoretical point of view. A parasite may be stamped out by destroying its germs, but a pathological product can only be annihilated by removing the conditions which give rise to it.

It appears to me that this great problem will have to be solved for each zymotic disease separately, for analogy cuts two ways. I have dwelt upon the analogy of pathological modification, which is in favour of the xenogenetic origin of microzymes; but I must now speak of the equally strong analogies in favour of the origin of such pestiferous particles by the ordinary process of the generation of like from like.

It is, at present, a well-established fact that certain diseases, both of plants and of animals, which have all the characters of contagious and infectious epidemics, are caused by minute organisms. The smut of wheat is a well-known instance of such a disease, and it cannot be doubted that the grape-disease and the potato-disease fall under the same category. Among animals, insects are wonderfully liable to the ravages of contagious and infectious diseases caused by microscopic *Fungi*.

In autumn it is not uncommon to see flies, motionless upon a window-pane, with a sort of magic circle, in white, drawn round them. On microscopic examination, the magic circle is found to consist of innumerable spores, which have been thrown off in all directions by a minute fungus called *Empusa muscæ*, the spore-forming filaments of which stand out like a pile of velvet from the body of the fly. These spore-forming filaments are connected with others, which fill the interior of the fly's body like so much fine wool, having eaten away and destroyed the creature's viscera. This is the full-grown condition of the *Empusa*. If traced back to its earlier stages, in flies which are still active, and to all appearance healthy, it is found to exist in the form of minute corpuscles which float in the blood of the fly. These multiply and lengthen into filaments, at the expense of the fly's substance; and when they have at last killed the patient, they grow out of its body and give off spores. Healthy flies shut up with diseased ones catch this mortal disease and perish like the others. A most competent observer, M. Cohn, who studied the development of the *Empusa* in the fly very carefully, was utterly unable to discover in what manner the smallest germs of the *Empusa* got into the fly. The spores could not be made to give rise to such germs by cultivation; nor were such germs discoverable in the air, or in the food of the fly. It looked exceedingly like a case of Abiogenesis, or, at any rate, of Xenogenesis; and it is only quite recently that the real course of events has been made out. It has been ascertained, that when one of the spores falls upon the body of a fly, it begins to germinate and sends out a process which bores its way through the fly's skin; this, having reached the interior cavities of its body, gives off the minute floating corpuscles which are the earliest stage of the *Empusa*. The disease is "contagious," because a healthy fly coming in contact with a diseased one, from which the spore-bearing filaments protrude, is pretty sure to carry off a spore or two. It is "infectious" because the spores become scattered about all sorts of matter in the neighbourhood of the slain flies.

The silkworm has long been known to be subject to a very fatal contagious and infectious disease called the *Muscardine*. Audouin transmitted it by inoculation. This disease is entirely due to the development of a fungus, *Botrytis Bassiana*, in the body of the caterpillar; and its contagiousness and infectiousness are accounted for in the same way as those of the fly-disease. But of late years a still more serious epizootic has appeared among the silkworms; and I may mention a few facts which will give you some conception of the gravity of the injury which it has inflicted on France alone.

The production of silk has been, for centuries, an important branch of industry in Southern France; and in the year 1853 it had attained such a magnitude, that the annual produce of the French sericulture was estimated to amount to a tenth of that of the whole world, and represented a money value of 117,000,000 of francs, or nearly five millions sterling. What may be the sum which would represent the money-value of all the industries connected with the working up of the raw silk thus produced is more than I can pretend to estimate. Suffice it to say, that the city of Lyons is built upon

French silk, as much as Manchester was upon American cotton before the civil war.

Silkworms are liable to many diseases; and, even before 1853, a peculiar epizootic, frequently accompanied by the appearance of dark spots upon the skin (whence the name of "Pébrine" which it has received), had been noted for its mortality. But in the years following 1853 this malady broke out with such extreme violence, that, in 1856, the silk-crop was reduced to a third of the amount which it had reached in 1853; and, up till within the last year or two, it has never attained half the yield of 1853. This means not only that the great number of people engaged in silk-growing are some thirty millions sterling poorer than they might have been; it means not only that high prices have had to be paid for imported silkworm-eggs, and that, after investing his money in them, in paying for mulberry-leaves and for attendance, the cultivator has constantly seen his silkworms perish and himself plunged in ruin,—but it means that the looms of Lyons have lacked employment, and that for years enforced idleness and misery have been the portion of a vast population which, in former days, was industrious and well to do.

In 1858 the gravity of the situation caused the French Academy of Sciences to appoint Commissioners, of whom a distinguished naturalist, M. de Quatrefages, was one, to inquire into the nature of this disease, and, if possible, to devise some means of staying the plague. In reading the Report* made by M. de Quatrefages, in 1859, it is exceedingly interesting to observe that his elaborate study of the Pébrine, forced the conviction upon his mind that, in its mode of occurrence and propagation, the disease of the silkworm is, in every respect, comparable to the cholera among mankind. But it differs from the cholera, and, so far, is a more formidable disease, in being hereditary, and in being, under some circumstances, contagious, as well as infectious.

The Italian naturalist, Filippi, discovered in the blood of the silkworms affected by this strange disease a multitude of cylindrical corpuscles, each about $\frac{1}{6000}$ of an inch long. These have been carefully studied by Lebert, and named by him *Panhistophyton*; for the reason that, in subjects in which the disease is strongly developed, the corpuscles swarm in every tissue and organ of the body, and even pass into the undeveloped eggs of the female moth. But are these corpuscles causes, or mere concomitants, of the disease? Some naturalists took one view and some another; and it was not until the French Government, alarmed by the continued ravages of the malady and the inefficiency of the remedies which had been suggested, dispatched M. Pasteur to study it, that the question received its final settlement; at a great sacrifice, not only of the time and peace of mind of that eminent philosopher, but, I regret to have to add, of his health.

But the sacrifice has not been in vain. It is now certain that this devastating, cholera-like, Pébrine is the effect of the growth and multiplication of the *Panhistophyton* in the silkworm. It is contagious and infectious because the corpuscles of the *Panhistophyton* pass away from the bodies of the diseased caterpillars, directly or indirectly, to the alimentary canal of healthy silkworms in their neighbourhood; it is hereditary, because the corpuscles enter into the eggs while they are being formed, and consequently are carried within them when they are laid; and for this reason, also, it presents the very singular peculiarity of being inherited only on the mother's

* Etudes sur les Maladies Actuelles des Vers à Soie, p. 53.

side. There is not a single one of all the apparently capricious and unaccountable phenomena presented by the Pébrine, but has received its explanation from the fact that the disease is the result of the presence of the microscopic organism *Panhistophyton*.

Such being the facts with respect to the Pébrine, what are the indications as to the method of preventing it? It is obvious that this depends upon the way in which the *Panhistophyton* is generated. If it may be generated by Abiogenesis, or by Xenogenesis, within the silkworm or its moth, the extirpation of the disease must depend upon the prevention of the occurrence of the conditions under which this generation takes place. But if, on the other hand, the *Panhistophyton* is an independent organism, which is no more generated by the silkworm than the mistletoe is generated by the oak, or the apple-tree, on which it grows, though it may need the silkworm for its development in the same way as the mistletoe needs the tree, then the indications are totally different. The sole thing to be done is to get rid of and keep away the germs of the *Panhistophyton*. As might be imagined, from the course of his previous investigations, M. Pasteur was led to believe that the latter was the right theory; and guided by that theory, he has devised a method of extirpating the disease, which has proved to be completely successful wherever it has been properly carried out.

There can be no reason, then, for doubting that, among insects, contagious and infectious diseases, of great malignity, are caused by minute organisms which are produced from preexisting germs, or by Homogenesis; and there is no reason, that I know of, for believing that what happens in insects may not take place in the highest animals. Indeed, there is already strong evidence that some diseases of an extremely malignant and fatal character to which man is subject are as much the work of minute organisms as is the Pébrine. I refer for this evidence to the very striking facts adduced by Professor Lister in his various well-known publications on the antiseptic method of treatment. It seems to me impossible to rise from the perusal of those publications without a strong conviction that the lamentable mortality which so frequently dogs the footsteps of the most skilful operator, and those deadly consequences of wounds and injuries which seem to haunt the very walls of great hospitals, and are, even now, destroying more men than die of bullet or bayonet, are due to the importation of minute organisms into wounds, and their increase and multiplication; and that the surgeon who saves most lives will be he who best works out the practical consequences of the hypothesis of Redi.

I commenced this Address by asking you to follow me in an attempt to trace the path which has been followed by a scientific idea, in its long and slow progress from the position of a probable hypothesis to that of an established Law of Nature. Our survey has not taken us into very attractive regions; it has lain, chiefly, in a land flowing with the abominable, and peopled with mere grubs and mouldiness. And it may be imagined with what smiles and shrugs practical and serious contemporaries of Redi and of Spallanzani may have commented on the waste of their high abilities in toiling at the solution of problems which, though curious enough in themselves, could be of no conceivable utility to mankind.

Nevertheless you will have observed, that before we had travelled very far upon our road, there appeared, on the right hand and on the left, fields laden with a harvest of golden grain, immediately convertible into those things

which the most sordidly practical of men will admit to have value—namely, money and life.

The direct loss to France caused by the Pébrine in seventeen years, cannot be estimated at less than fifty millions sterling; and if we add to this what Redi's idea, in Pasteur's hands, has done for the wine-grower and for the vinegar-maker, and try to capitalize its value, we shall find that it will go a long way towards repairing the money losses caused by the frightful and calamitous war of this autumn.

And as to the equivalent of Redi's thought in life, how can we overestimate the value of that knowledge of the nature of epidemic and epizootic diseases, and consequently of the means of checking, or eradicating, them, the dawn of which has assuredly commenced?

Looking back no further than ten years, it is possible to select three (1863, 1864, and 1869) in which the total number of deaths from scarlet-fever alone, amounted to ninety thousand. That is the return of killed, the maimed and disabled being left out of sight. Why, it is to be hoped that the list of killed in the present bloodiest of all wars will not amount to more than this! But the facts, which I have placed before you, must leave the least sanguine without a doubt that the nature and the causes of this scourge will, one day, be as well understood as those of the Pébrine are now; and that the long-suffered massacre of our innocents will come to an end.

And thus mankind will have one more admonition that "the people perish for lack of knowledge;" and that the alleviation of the miseries, and the promotion of the welfare, of men must be sought, by those who will not lose their pains, in that diligent, patient, loving study of all the multitudinous aspects of Nature, the results of which constitute exact knowledge, or Science.

It is the justification and the glory of this great Meeting that it is gathered together for no other object than the advancement of the moiety of Science which deals with those phenomena of Nature which we call physical. May its endeavours be crowned with a full measure of success!

REPORTS

ON

THE STATE OF SCIENCE.

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Report of the Committee appointed to consider and report on the various Plans proposed for Legislating on the subject of Steam-Boiler Explosions, with a view to their Prevention,—the Committee consisting of Sir William Fairbairn, *Bart., C.E., LL.D., F.R.S., &c.,* Sir Joseph Whitworth, *Bart., C.E., F.R.S.,* John Penn, *C.E., F.R.S.,* Frederick J. Bramwell, *C.E.,* Hugh Mason, Samuel Rigby, Thomas Schofield, Charles F. Beyer, *C.E.,* Thomas Webster, *Q.C., and* Lavington E. Fletcher, *C.E.*

To the frequent occurrence of steam-boiler explosions, with the loss of life and property caused thereby, attention was called in a Report read before the Mechanical Section of the British Association last year at Exeter, and in a Paper read the year before that, at Norwich. These sad catastrophes still continue with unabated frequency. In the interval between the Norwich and Exeter Meetings, 46 explosions occurred, killing 78 persons and injuring 114 others. Since then 57 more explosions have occurred, killing 99 more persons and injuring 96 others. So great is the regularity with which these catastrophes occur, that it was stated at Exeter that it was to be feared that as many lives would be lost by explosions before the next Meeting as had been lost since the last. This, it will be seen from the figures just given, has been more than fulfilled. Taking the average of a number of years, it appears that about 50 explosions occur every year, killing about 75 persons and injuring as many others.

It is not intended in this Report to enter on a consideration of the causes of steam-boiler explosions. That has already been done on other occasions. It need, therefore, merely be stated in passing that the experience of another year only confirms the Committee in their opinion, previously expressed, that explosions are not accidental, that they are not mysterious, but that they arise from the simplest causes, and may be prevented by the exercise of common knowledge and common care. Boilers burst simply from weakness, that weakness arising in some cases from original malconstruction, in others from defective condition consequent on wear and tear, and in others again from neglect of attendants (through allowing the plates over the furnace to become overheated from shortness of water &c.). Competent inspection

is adequate to detect the weakness of the boiler in time to prevent explosion, whether that weakness arise from malconstruction or from defective condition, while it tends to stimulate attendants to carefulness, and thus to diminish the number of those explosions arising from oversight. It is very generally thought that most explosions result from the neglect of the attendant. Such, however, is not the case. On analyzing the causes of the explosions that occurred from the 1st of January 1861 to the 18th of June 1870, it appears that 120 explosio equal to 40 per cent. of the whole number, were due to the malconstruction of the boilers, either in the shells or fittings; 88 explosions, equal to 29 per cent., were due to the defective condition of the boilers, either in the shells or fittings; 44 explosions, equal to 15 per cent., were due to the failure of the seams of rivets at the bottom of externally fired boilers; 38, equal to 13 per cent., were due to overheating of the plates; 5, equal to 2 per cent., were due to excessive pressure of steam through the attendants tampering with safety-valves; while 1, equal to, say, $\frac{1}{2}$ per cent., occurred to an economizer, but whether from gas or overpressure of steam is uncertain; and 1 other, equal to, say, $\frac{1}{2}$ per cent., arose from causes entirely independent of the construction or condition of the boiler, and may thus be termed "accidental." Of those due to overheating of the plates, 30 explosions, equal to 10 per cent. of the whole number, arose from shortness of water; 6, equal to 2 per cent., from incrustation; 1, equal to $\frac{1}{2}$ per cent., from the use of boiler-compositions; and 1, equal to $\frac{1}{2}$ per cent., from causes requiring further consideration. The total number of these explosions the causes of which were ascertained, was 297. From this list it will at once be seen that the two leading causes of the explosions enumerated therein were malconstruction and defective condition, a small proportion only being due to the neglect of the attendants. It may be put shortly, that for every explosion due to the boiler-minder through neglecting the water-supply &c., six are due to the boiler-maker or boiler-owner through making or using bad boilers. It is clear, therefore, that the adoption of competent inspection by every boiler-owner in the kingdom would do much to prevent the constant recurrence of boiler explosions, and to save the greater part of the 75 lives annually sacrificed. This fact is now generally admitted; and hence the question is not unfrequently asked, Since competent inspection would prevent explosions, and steam-users neglect so simple a precaution, why is not inspection enforced by law? Juries, in bringing in verdicts consequent on steam-boiler explosions, frequently recommend that the Government should render inspection compulsory; and this view appears to be very widely entertained, in consequence of which various plans for legislative enactment have been proposed. The object of this Report is to deal with these plans, and give the result of the Committee's deliberations thereon.

This is a particularly opportune moment for the presentation of such a Report. Last Session of Parliament a Select Committee of the House of Commons was appointed to inquire into the cause of steam-boiler explosions, and the best means of preventing them; and this Committee, whose labours are not yet completed, have been investigating whether it is expedient that boiler-inspection should be enforced by law, and, if so, what is the best way of enforcing it. It is therefore important at this time that discussion on this subject should be encouraged, and suggestions from all parties obtained. It is trusted that this Report will aid in promoting this object and in arriving at the best means of rendering the inspection of boilers universal throughout the entire country.

With these introductory remarks the Committee will proceed to the con-

sideration of such of the plans "proposed for legislating on the subject of steam-boiler explosions, with a view to their prevention," as have come under their notice.

Five systems of compulsory inspection appear to be now before the public. These may each be stated and considered in turn.

Plan No. 1.—It has been proposed that the inspection of all the boilers in the kingdom should be carried out by the Board of Trade. To this plan there are many objections. On the one hand, it would impose on the Government additional burdens, which they have expressed themselves unwilling to incur; while on the other it would prove harassing to the steam-user. It would, it is feared, be found to work arbitrarily. Such a system would lack that elasticity which is necessary to conform to the convenience of the individual steam-user. There would be a great danger of its hampering progress. It would certainly not find favour with the generality of steam-users, nor ever be voluntarily accepted by them except as the last resort.

Plan No. 2.—A second proposition is, that, instead of the inspection being carried out by the Board of Trade, it should be carried out by town councils or other local authorities, such authorities appointing their own inspectors. This plan would admit of more elasticity than the previous one, inasmuch as the inspection would emanate from several centres instead of from one. From the fact, however, of the inspections emanating from several centres instead of from one, an element of discord would be introduced, from which many contradictions and many absurdities would ensue. If it were a question of establishing Greenwich time in every market town and country village throughout the kingdom, there might be little difficulty in effecting such an object by such an organization, since Greenwich time, by the help of the Astronomer Royal, could be put beyond all question, and the work of establishing it throughout the kingdom would be one of diffusion and not of origination. To regulate the construction of steam-boilers, however, is a totally different matter. The science of boiler-making is a growing one. It is in a transition state; and, in spite of the amount of information constantly disseminated, great ignorance prevails with regard to it. In consequence of this, one corporation would declare a boiler safe which another corporation would declare unsafe, so that a boiler carried by rail from one part of the country to another might be counted safe at the beginning of its journey and unsafe at the end. For instance: in Lancashire the practice of strengthening flue-tubes at the ring-seams with flanged joints or hoops of T-iron, or other suitable section, is highly approved. In fact it is thought that no high-pressure boiler should be constructed nowadays without these appliances. In Cornwall, however, nothing can convince steam-users of their necessity, and Cornishmen persistently adhere to the ignorant superstition which the Franklin Institute of Pennsylvania endeavoured to dispel thirty-four years ago, viz. that a boiler cannot explode as long as it is properly supplied with water. They appear to believe that furnace-tubes, though of great length and diameter, and though worked at high pressures of steam, can only collapse from the neglect of the water-supply, or, in other words, from the neglect of the attendant and not of the owner or the maker. In Cornwall, boiler-flue after boiler-flue collapses, simply from weakness, till the Cornish boiler stands in the return of explosions as one of the most dangerous. These explosions are the result of gross malconstruction, coupled with neglected condition. Yet Cornishmen will not see it, and they only attribute every explosion to shortness of water. Local administration under such circum-

stances would be powerless; while, even apart from undue influence, and simply from the want of due experience in so important a matter as the construction of steam-boilers, the decisions of local authorities would be frequently contradictory. Such a system would reintroduce the evils we are trying to eradicate from our courts of law, viz. that a verdict given in one court is frequently contradicted in another. Though the plan of intrusting the inspection of all the boilers in the kingdom to local authorities might answer in the neighbourhood of some of the large manufacturing centres, it would not do so throughout the entire country.

Plan No. 3.—Another proposition is, to hand over the duty of inspecting and certifying all the boilers in the kingdom to divers authorized parties, such as accredited boiler-makers, private-inspection associations, insurance companies, &c. This plan would, like the one just referred to, be liable to produce contradictory verdicts, while it has the additional objection that it fails to secure the responsibility of the inspections. To allow certificates to be granted by boiler-makers would be a most invidious course. It could not be a wholesome practice, especially under the influence of keen competition, for one maker to be called in to approve or condemn a boiler made by another; while the fact that 40 per cent. of the explosions that happen are due to malconstruction, shows that boiler-makers are not, after all, good judges in this matter,—a view which is corroborated by the unsatisfactory and contradictory evidence frequently given by them at coroners' inquests consequent on boiler explosions. Further, it is presumed that every boiler-owner would have to pay for his own certificate; so that on this system the most indulgent offices would clearly get the greatest amount of custom, and those which only granted faithful certificates would be driven out of the market by the less scrupulous. Under these circumstances it is feared that the sale of certificates would soon degenerate into a sale of indulgences. Besides this, how is this system to be practically worked? Who is to see that the steam-user has the certificates on his boilers regularly renewed as they fall out? These certificates would extend for a year only from each "entire" examination, and would lapse at different parts of the year. A steam-user with twelve boilers would want twelve certificates every year; and one of these might fall out each month. Is the Government to undertake the responsibility of seeing that these certificates are regularly renewed? Is it to inspect the inspectors? Such a plan, it is thought, would be impracticable, while it would be after all but another form of Governmental inspection, and one of a very complicated description.

Plan No. 4.—The fourth plan starts on the same basis as the preceding ones, viz. that of rendering inspection compulsory, and recommends that Parliament should enact that no boiler should be worked unless periodically inspected and certified, at least once a year, as safe and trustworthy. Instead, however, of intrusting the duty of carrying out these inspections and granting the certificates to the Board of Trade, or to the town councils, or other local authorities, or to certified boiler-makers, private-inspection associations, or insurance companies, it proposes that there should be formed a National Steam-Users' Board, and that this Board should be empowered to carry out the system of inspection required, including the granting of certificates, fixing the rate of charge for each boiler, &c. This Board to be an honorary and representative body, about one-half of its members being men of commerce (that is to say, mill-owners or others using boilers for mercantile purposes), and the remainder to be men of science (that is to say, engineers and others competent to advise on matters relating to the inspection of

boilers, and to add weight to the counsels of the Board)*. None of the members of the Board to retain office longer than four years without re-election, one-fourth retiring every year, so that every four years the Board would be entirely recruited, either with new members or re-elected ones. The Board to be appointed in such a way as to secure the fair representation of the general body of steam-users, and to merit their confidence, the appointment being effected either by popular election, every steam-user having a vote for each of his boilers, or by any other appropriate method. If preferred, there might be a number of district steam-boards with geographical limits assigned to each, instead of a single national one; and it is well worthy of consideration which would be the better plan of the two. If the plan of district boards were adopted, it would then be well for an annual conference to be held, composed of deputies from each of the district boards, in order that the results of the working of each district might be compared; and this, it is thought, would promote a wholesome rivalry.

The following are set forth as some of the distinctive features and advantages of this system of administration, and as equally applicable whether the central Steam Board or the district ones are adopted.

No. 1. This system would throw no administrative responsibility on the Government, whether of a financial or engineering character.

No. 2. It would secure the integrity and efficiency of the inspections, inasmuch as the work would not be undertaken for profit, and the Board or Boards would be established on too wide a basis to be influenced by local or private interests. At the same time the boiler-owners would be protected from arbitrary interference, inasmuch as the inspections in each case would be controlled by a Board or Boards composed principally of steam-users, and appointed by themselves.

No. 3. This plan would secure to the country a large amount of valuable engineering information. It would afford the opportunity of ascertaining how many boilers there are in the kingdom, how many varieties of construction, and how many boilers to each class, as well as the various pressures at which they are worked. Also it would afford the opportunity of ascertaining the approximate horse-power throughout the whole kingdom, as well as the consumption of fuel for boiler-purposes. Added to this it would afford the means, at a perfectly nominal outlay per boiler, of establishing a fund for scientific research on any doubtful questions with regard to the safety and economical working of steam-boilers and engines.

The above is but a very brief outline of the fourth plan proposed for carrying out compulsory inspection; and it is found impossible in the compass of this Report to enter upon it in detail. The sketch given, however, may be sufficient to afford a general idea. It will be seen that this plan is independent of Governmental interference further than the passing of an act, in the first instance, to enforce the inspection of every boiler in the kingdom, and to empower the Steam Board or Boards to carry out these inspections and adjust the rates, &c. Thus the steam-users would be left to govern themselves, a responsibility with which it is thought they might be intrusted, since they have a strong desire to avoid Governmental interference, and they would know that, unless they succeeded, the Government would take the matter into its own hands. The Committee consider this plan calculated to guard the inspections against being lax and contradictory on the one hand,

* It might be desirable that clauses should be introduced to prevent parties with special and private interests having a seat at the Board; but details of this character are purposely avoided in this sketch.

or arbitrary and oppressive on the other—dangers against which the three previous plans would not, they think, afford sufficient protection; and thus they regard the proposed national Steam Board or national system of district Boards as adequate to the prevention of explosions without harassing steam-users.

Plan No. 5.—This plan differs from the preceding inasmuch as it does not propose to enforce inspection directly by law, but to impose a heavy penalty on the occurrence of every explosion, with the view of inducing steam-users to take precautionary measures, and have their boilers inspected*. With this penalty system it is proposed to ally the principle of steam-boiler insurance by joint-stock companies, thinking that while boiler-owners would be driven by the penalty to insure, insurance companies would be driven to inspect, as the penalty, though falling in the first instance on the owner, would be ultimately paid by the insurance company.

On considering this proposition, it appears by no means clear that a penalty would have the effect of inducing all steam-users to enrol their boilers. The incredulity of many as to the possibility of their boilers exploding is so great that nothing would convince them but the occurrence of the calamity itself. It would therefore, it is thought, be some time before the penalty system took effect, and, this being the case, several lives would be lost in the meantime. Indeed, unless the simple announcement that the Government had established a penalty were sufficient to promote general enrolment, the system could not come into force until the penalty was exacted; and before this could be done, explosions must happen, and thus lives be lost. Still the Committee cannot doubt, though the effect of the penalty might be tardy in its operation, that in process of time it would induce many steam-users, if not all, to avail themselves of inspection.

Passing over the question as to the success of the penalty in promoting inspection, the next question is as to the value of the inspections by competing joint-stock insurance companies. This is by no means a simple subject, and one on which a great deal of misapprehension occurs. A few brief remarks upon it are all that can be offered in the limits of this paper.

Commercial insurance is founded on the principle of a commutation of risks. Given the number of fires that occur per annum on an average, and we have the risk of fire-insurance. Given the number of deaths that occur throughout the country per annum, and we have the risk of life-insurance. Given the number of persons injured every year by railway-travelling, and we have the risk of railway-passenger insurance. Now, it will be seen in these cases that the companies adopt little or no preventive measures. It is true that before a house or a life is insured, a general examination is made in each case; but these are not followed up by a series of preventive measures. In the case of accidental-death insurance, no precautionary measures are adopted whatever. A passenger, on taking his railway ticket, takes also an insurance ticket, and thereby enters what may be termed a legalized lottery. If he is injured in his journey he receives some return for his outlay; if not, he loses it, and the company gains it. This is a perfectly above-board transaction. It is quite understood that the company adopt no precautionary measures. They do not inspect the railway-line, they do not inspect the axles or tires of the carriages, the points and crossings, the signals or the signalmen. The whole matter is understood on both sides to be simply a commutation of risk; and the company merely profess to insure against

* These penalties to be applied to forming a general fund for compensating those injured by the explosions.

accident. Now it will be seen that before this principle can be applied to the prevention of boiler explosions, some serious qualifications must be made. It has already been seen that boiler explosions are not accidental. To term a boiler explosion an accident is to mislead, and thus do much mischief. Boiler explosions may be prevented by common knowledge and common care; and these every boiler-owner is bound in justice to his workmen to exercise. A boiler-owner has no right to insure himself against the pecuniary results of his own neglect which may cost the lives of his workpeople. To this it may be replied that when the principle of insurance has been applied to boilers, inspection has been coupled with it, and further, that it is the interest of insurance offices that such should be the case, since, inasmuch as they have dividends to pay, they are bound to inspect in self-protection. This view obtains very general currency. It is, however, a total fallacy that the joint-stock insurance principle, as at present applied, affords any inducement to the adoption of inspection. This can be plainly shown in a few words. The object of a joint-stock company is clearly pecuniary profit—not philanthropy; and this being the case, such a company would not expend a pound to save a shilling. Now it appears, from data which have been accumulated for years, that the risk of explosion with steam-boilers is about one in two thousand; so that the cost of insurance is 1*s.* per £100. The cost of an annual "entire" examination, which is essential to sound inspection, may be taken in round numbers as about 20*s.* per boiler. Thus, inspection costs about 20*s.*, while insurance costs 1*s.*; or, at all events, inspection costs much more than insurance. Consequently it will pay an insurance office better to allow boilers to blow up, and pay compensation, than to prevent explosions and pay for inspection. Inspection is dear, insurance is cheap. Inspection eats away the dividends. The interest of a joint-stock company, therefore, is to lavish insurance and stint inspection.

There are further points in the mode in which joint-stock insurance is at present applied to steam-boilers which may be called attention to. Insurance companies adopt scales of charges according to the risk run; and thus they class the boilers A, B, and C, as they may be first-, second-, or third-rate. This is insuring boilers simply on the principle of risks, and ignores altogether the danger to life. If boilers can only be worked at a risk, they should not be worked at all. Again, the charge for insurance rises according to the pressure of the steam. This is to tax progress, and make a market of engineering enterprise. Again, insurance companies charge so much for the first £100 insured on a boiler, the same amount for the second £100, the same for the third £100, and so on, though the payment for the insurance of the first £100 included the charge for inspection. In this arrangement the value of inspection appears to be ignored. The danger of explosion is assumed to be as great after the charge has been paid for inspection as before. An accidental-death company, insuring railway-passengers' lives, could not adopt a scale of charges that would more consistently ignore the principle of prevention, and adopt that of hazards. Again, insurance companies pay compensation in case of minor damage, which emboldens a boiler-owner to neglect any precautionary advice given in consequence of the inspections. If he employ an inferior attendant in order to save 5*s.* a week in his wages, and the boiler becomes injured thereby, the cost of repair is paid by the company, and not by himself. This system entirely absolves a boiler-owner from the results of his own neglect.

These remarks will suffice to show that the principle of insurance, as at present applied to steam-boilers by joint-stock companies, is not all that is

to be desired for the prevention of steam-boiler explosions, and that before the Government will be justified in handing over the inspection of all the boilers in the kingdom to a number of competing joint-stock companies, considerable modifications will have to be enforced; and it will be well now to consider whether the imposition of the proposed penalty would have the desired effect, or whether any other steps would be necessary.

The penalty upon the boiler-user in the event of explosion would, as already stated, ultimately fall upon insurance companies—that is to say, in those cases where the boilers were enrolled. Now if that penalty were made sufficiently heavy, it might make it more expensive for companies to permit explosions and pay compensation, than to prevent them and pay for inspection, and thus just reverse the position that obtains at present. For this it would be necessary that the penalty should not be less than £1000 or £2000. Added to the penalty imposed on the boiler-owner, in the event of explosion, to induce him to enrol, it might be well to impose another penalty of equal amount on the company, more fully to induce them to inspect. The first of these penalties, the one imposed on the boiler-owner, should be exacted unconditionally; the other, imposed on the insurance company, only after it had been shown on an examination by a Government officer that the company had failed in their duty. Added to the imposition of these penalties, it would be necessary for it to be enacted that no company should have more than one rate of charge; otherwise they would meet the risk on dangerous boilers simply by raising the rate. A fixed rate would also put an end to the taxing of high-pressure steam, as the rate would be the same for 10 lbs. as for 100 lbs. Added to this, the present system of insuring against minor damages should be prohibited, as this completely destroys the owner's responsibility. Such are some of the restrictions which it appears necessary to impose upon the principle of joint-stock insurance before it would be applicable, by a number of competing companies, to steam-boilers, with a view to the prevention of explosions.

The Committee are not without apprehensions, however, that though the principle of joint-stock insurance might be surrounded with a series of checks and counterchecks, it yet would lead to inspection being cut down to the lowest possible point. On the other hand, were the inspection enforced by law, and nationally administered, either by a central Steam Board or by a series of district ones, they consider that a far more generous system would be secured. The Steam Boards, uninfluenced either by private or local interests, or by the desire to accumulate profits, would take altogether higher ground, and inspect, not simply in their own interests, and just sufficiently to narrowly escape explosion, but with a view to assist steam-users, disseminate practical information on the making and management of boilers, and promote progress. These objects would be altogether foreign to competing joint-stock insurance companies.

The Committee have now stated, they trust impartially, the various plans which have come under their notice, remarking, as they proceeded, on such of the points in each as appeared to them to be defective, and they would now beg to solicit the most ample discussion of this important subject.

In drawing this Report to a close, the Committee wish to make a brief reference to the one they presented to the Mechanical Section of the British Association last year, on the subject of "Coroners' Inquiries in connexion with Boiler Explosions." In that Report they pointed out the defects in these investigations, and how necessary it was that improvements should be effected, expressing their belief that full investigation and plain-speaking would, of themselves, do much to prevent the recurrence of these catastrophes.

The Committee still hold this view, and think that, had coroners' verdicts been as satisfactory as they might have been, boiler explosions would not have been as numerous as they now are. With the additional experience of another year they feel compelled to take one other step in advance, and they have come to the conclusion that the time has arrived when the Government should enforce the periodical inspection of all steam-boilers, though, as already stated, they do not think that the Government should turn boiler-inspector*. They are convinced that explosions might be, and ought to be, prevented; that competent inspection is adequate for this purpose, and that any well-organized system of inspection, extended throughout the entire country, would practically extinguish boiler explosions, and save the greater part of the 75 lives now annually sacrificed thereby.

(Signed on behalf of the Committee)

William Fairbairn, *Chairman.*

Manchester, September 12th, 1870.

Report of the Committee appointed for the purpose of calling the attention of Her Majesty's Government to the importance of completing, without delay, the valuable investigation into the composition and geological distribution of the Hæmatite Iron-ores of Great Britain and Ireland, which has been already in part published in the Memoirs of the Geological Survey,—consisting of Prof. Stokes, *F.R.S.,* Prof. Harkness, *F.R.S., and* R. A. C. Godwin-Austen, *F.R.S.*

The Committee appointed at the Exeter Meeting of the Association "for the purpose of calling the attention of Her Majesty's Government to the importance of completing, without delay, the valuable investigation into the composition and geological distribution of the hæmatite iron-ores of Great Britain and Ireland, which has been already in part published in the Memoirs of the Geological Survey," present to the General Committee the following Report:—

In execution of their duty, the Committee had in the first instance to consider to what department of Government the application should be addressed. For the reasons stated in the application itself, they decided that it belonged to the Education department. They accordingly addressed the following letter to the Lord President of the Council:—

"Lensfield Cottage, Cambridge,
17th December, 1869.

"My Lord,—I have the honour to inform your Lordship that, at the last Meeting of the British Association for the Advancement of Science, a resolution was passed appointing a Committee 'for the purpose of calling the attention of Her Majesty's Government to the importance of completing, without

* From the conclusion that "the time has arrived when the Government should enforce the periodical inspection of all steam-boilers," one of the members of the Committee, F. J. Bramwell, Esq., C.E., wishes to express his dissent, "as in his judgment not even the best of the modes yet suggested for an inspection would be free from hindering improvements in the construction and use of steam-boilers, and, in his opinion, the saving of some out of the few lives annually now lost would be dearly purchased by fettering the progress of mechanical engineering."

delay, the valuable investigation into the composition and geological distribution of the hæmatite iron-ores of Great Britain and Ireland, which has been already in part published in the Memoirs of the Geological Survey.'

"Your Lordship is doubtless aware of the remarkable process invented some years ago by Mr. Bessemer, for the conversion of crude cast iron into steel or wrought iron,—a process by the application of which those important materials can be manufactured at a much cheaper rate than formerly. The royalty which at present exists on iron to which the Bessemer process has been applied will shortly expire, and its expiration will probably give a great impetus to the iron trade of the country.

"It is not, however, every iron-ore that iron-masters have been in the habit of employing which can be used for the production of cast iron destined for conversion by the Bessemer process; for there are certain impurities which that process fails to remove, and which are extremely injurious to steel or wrought iron. This difficulty is got over by preparing the iron from hæmatite, an iron-ore which is free from those impurities.

"Accordingly, on the expiration of the Bessemer royalty, a great demand for hæmatite is likely to arise; and it will be important for the iron trade of the country that it should be known where hæmatite is to be found. For many of the counties of England the requisite information is contained in the Memoirs referred to in the resolution quoted above; and the object of the British Association is merely to urge on Her Majesty's Government the importance of continuing and completing, without delay, the investigation thus so ably begun.

"Although the application of the British Association relates to trade, I have addressed myself to your Lordship rather than to the President of the Board of Trade, because it is to be presumed that the investigation would be best completed by the same body by which it was begun, namely the Staff of the Geological Survey; and that belongs to the department over which your Lordship presides.

"The Committee will be ready to wait on your Lordship, should you think a personal interview expedient. The Committee consists of Professor Harkness, President of the Geological Section at the Exeter Meeting of the British Association, R. Godwin-Austen, Esq., F.R.S., Vice-President, and myself.

"I have the honour to be, &c.,

"G. G. STOKES."

"*To the Right Honourable*
The Earl de Grey and Ripon,
Lord President of the Council."

To this application the following reply was received:—

"Science and Art Department, London, W.,
8th day of February, 1870.

"Sir,—Your letter to the Lord President, of the 17th of December, 1869, stating that, at the last Meeting of the British Association for the Advancement of Science, a resolution was passed appointing a Committee 'for the purpose of calling the attention of Her Majesty's Government to the importance of completing, without delay, the valuable investigation into the composition and geological distribution of the hæmatite iron-ores of Great Britain and Ireland, which has been already in part published in the Memoirs of the Geological Survey,' has been under the consideration of the Lords of the Committee of Council on Education.

"I am directed by their Lordships to inform you that, after consulting with Sir Roderick Murchison on the subject, they have come to the conclusion that

they are not in a position to direct that the former investigation shall be continued by the officers of the Geological Survey.

"The investigation referred to was not made at the public cost; and it does not appear to My Lords that a special inquiry of this nature, involving considerable additional expense, falls within the object for which the sum voted by Parliament for the Geological Survey has been granted.

"I am, Sir,

"Your obedient Servant,

"NORMAN MACLEOD,

Assist. Secretary."

"*Prof. G. G. Stokes, M.A., F.R.S.,*
Lensfield Cottage, Cambridge."

After this reply, the Committee did not think that they could take any further steps in the matter.

G. G. STOKES.
ROBERT HARKNESS.
R. GODWIN-AUSTEN.

Report on the Sedimentary Deposits of the River Onny. *By the* Rev. J. D. LA TOUCHE.

THE principal rainfalls in the valley which supplies the waters of the Onny during the past year, occurred from December 17th to 20th, January 6th to 9th, 13th and 14th, February 1st to 10th, and March 1st to 4th. At none of these dates did the river attain the height it has done on former occasions. For this reason, and the long-continued droughts, the results of these experiments have been rather barren.

The accompanying Table shows that the relation of deposit to rainfall is modified by many circumstances. As might be expected, the greatest quantity is attained when a flood takes place after continued wet weather. Thus, after the rains of last February, the floods of the 1st and 2nd of March were followed by the largest amount of deposit observed in the year; on this occasion from 1318 lbs. per minute on the 2nd, to 2128 lbs. per minute on the 3rd (that is, about 57 tons per hour), passed down.

In considering these quantities, it must be remembered that the Onny is a small stream: its width is 60 feet; the area of the section where these experiments are made is, at summer level, 92 square feet; and the discharge at a high flood amounts to about 80,000 cubic feet per minute. The area of the Severn at summer level is 512 square feet; and its discharge, under similar circumstances, would probably be about 900,000 cubic feet per minute. Assuming that the ratio of deposit in the water of the Severn were the same as that observed in the Onny, no less than 1239 tons per hour of solid matter would be carried by it in suspension past each spot. This, of course, leaves out of account the pebbles and sand, which are occasionally rolled along the bottom in great quantities.

Within the last year a gauge has been erected on the Severn, at Shrewsbury, at the cost of the grant made by the Association. A register of the floods has moreover been kept; but as yet there has been some difficulty in obtaining water for examination. This, it is hoped, may be done during the ensuing year, as well as at Hereford, where a record is regularly kept of a gauge on the Wye.

An attempt has been made, from the accompanying register, to estimate the total quantity of sediment carried down in suspension during the year. Each pair of succeeding entries in the fifth column, viz. "discharge per minute," have been added together, the sum divided by 2, and the quotient multiplied by the number of minutes between the observations. The result is a total of 3564 tons for the year.

The surface of the valley of the Onny is 84 square miles; and the effect of the above result would be (taking the average specific gravity of the Silurian rocks as 2·5) to reduce the level of the whole by ·0025, or $\frac{1}{400}$ of an inch. Probably, however, the rate of denudation during the year has been exceptionally low; and, besides, no account is here taken of any but suspended matter.

Date.	Hour of day.	Height on gauge.	No. of grains of sediment in 100 oz. of water.	Discharge of sediment per minute, in lbs.	Average rainfall over 84 square miles.
1869.					
December 17	3 P.M.	1·00	....	....	·45
"	9 P.M.	0·90			
" 18	11 A.M.	1·25	4·35	373	·19
"	6 P.M.	1·40	....	407	
" 19	9 A.M.	1·00	3·34	199	·24
" 20	5 P.M.	1·00	....	100	·50
1870.					
January 6	....	....	....	....	·19
" 7	10 A.M.	·50	4·62	121	·24
" 8	10 A.M.	·60	....	136	·23
"	12	·70	5·38	185	
"	3 P.M.	·80	9·50	347	
"	5 P.M.	·90	....	464	
"	10 P.M.	·90	....	464	
" 9	8 A.M.	·70	....	316	·11
" 13	....	....	....	....	·27
" 14	10 A.M.	1·00	13·46	792	·10
"	1 P.M.	·90	4·35	211	
February 1	....	....	....	....	·29
" 2	10 A.M.	·60	9·62	282	·18
" 3	10 A.M.	....	2·50	74	
" 6	6 P.M.	·30	....	....	·56
" 7	10 A.M.	·70	6·54	189	·43
"	6 P.M.	1·00	15·77	924	
"	10 P.M.	1·30	....	1270	
" 8	9 A.M.	·90	6·15	299	·54
"	5 P.M.	1·00	6·68	394	
"	10 P.M.	1·30	....	508	
" 9	8 A.M.	1·20	7·65	747	
" 10	11 A.M.	·60	....	206	
March 1	....	....	....	....	·54
" 2	10 A.M.	·60	12·31	362	·64
"	12	·60	23·73	847	
"	6 P.M.	·80	36·00	1318	
"	10 P.M.	·85	....	1531	
" 3	9 A.M.	·70	14·45	711	·16
"	12	....	29·85	2128	
"	1 P.M.	1·20	....		
"	4 P.M.	1·40	22·54	2104	
" 4	10 A.M.	·75	3·19	116	

Report of the Committee on the Chemical Nature of Cast Iron. The Committee consists of F. A. Abel, *F.R.S.,* D. Forbes, *F.R.S., and* A. Matthiessen, *F.R.S.*

We regret to have to report that it has not been in our power during the past year to make any important progress in the investigation of the chemical nature of cast iron, which was intrusted to us.

In the Appendix to the Report which we submitted last year, a process was described by which pure iron could be prepared in considerable quantities; and it was intended to apply this process at once to the preparation of the material necessary for our investigations. The apparatus and arrangements required for this purpose, however, have been unavoidably in a dismantled condition during the greater part of the year, in consequence of the reconstruction of the Laboratories of St. Bartholomew's Hospital. They are now again in working order, and it is hoped that the experiments will be resumed without much further delay.

Numerous experiments have been made with a view to ascertain whether the pure-iron sponge, prepared by the process above referred to, can be converted, by welding, into thoroughly solid masses without detriment to the purity of the metal. Hitherto the results obtained (though instructive in connexion with the physical properties of the pure metal) have not been of a promising nature in the particular direction desired. It is contemplated, however, to continue these experiments with the aid of facilities which, we believe, will be available for this purpose at the Royal Arsenal, Woolwich.

For the foregoing reasons we beg leave to suggest that the reappointment of this Committee be recommended; but we do not consider it necessary to apply for a grant of money on this occasion.

Report on the practicability of establishing "A Close Time" for the protection of indigenous Animals. By a Committee, consisting of Prof. Newton, *M.A., F.L.S.,* Rev. H. B. Tristram, *F.R.S.,* J. E. Harting, *F.L.S., F.Z.S.,* Rev. H. Barnes, *and* H. E. Dresser (Reporter).

The Committee appointed for the purpose of continuing investigations as to the advisability of establishing a close time for the preservation of our indigenous animals beg leave to report as follows:—Having regard to the state of business during the late session of Parliament, your Committee have not thought it expedient to press the object your Committee are directed to obtain on the attention of Members of the Legislature, or the general public. Your Committee have learnt with satisfaction that, in several cases where the provisions of the Sea-birds' Preservation Act have been enforced, very beneficial results have followed, instances of which are added in the appendix. In consequence hereof, your Committee see good reason to hope that an extension of similar protection to other groups of indigenous animals will be attended by similar happy results; and your Committee consider that such extension could not be better commenced than with the group of birds commonly known as "*wild fowl,*" comprising as that does, very many

kinds of birds which, being largely used as food, are of great value to the community, and are generally admitted to be entirely innocuous. At present, very great numbers of Wild Ducks, of many species, Snipes, Woodcocks, Plovers, and other kindred birds are killed during the spring months, even when in the act of breeding. The destruction thus effected cannot fail to continue the ever-increasing diminution of these birds, if indeed it does not promise, at no distant date, to result in their utter extermination. Accordingly, your Committee are unanimously of opinion that protection should be afforded by law, during the breeding-season, to such "wild fowl" as these, in order to prevent that result; while your Committee think that, with protection, these birds may long continue to furnish, at other times of the year, valuable food to the public, notwithstanding the changes which some parts of the country are undergoing through agricultural improvements and increase of the population.

Your Committee respectfully suggest the reappointment of this Committee.

Extract of a letter from H. L. Stevenson of Norwich.—"The beachmen at Salthouse (Norfolk) are delighted with the new Act, as, through summer shooters, their means of earning a few shillings were going fast. Only three or four pairs of Lesser Terns nested there this year; and, as the men reminded me, ten years ago they had forty or fifty pairs at least. I am sure the marshmen on the Broads would be equally glad of a close time there, as they complain to me of gentlemen shooting Snipe into May."

Extract of a letter from the Rev. H. F. Barnes of Bridlington.—"With regard to our Sea-bird Act, I am happy to tell you that here it has been very effective. * * * It renders the birds, however, remarkably tame. They sit on the cliffs only a few feet below the observer, and nod and bow in the most amiable manner, as if all that breathed must needs be kin. Then, again, they swim about the shore, on a calm day, like ducks in a pond. All this may safely be set down to the degree of immunity they have enjoyed. One noticeable and very valuable fact is, that they have bred (in small numbers) this year at Flamborough, which they have not done for the last twenty years."

Captain Hadfield, of Ventnor, in a communication to the 'Zoologist' (June 1870, p. 2184), has remarked on the "increase of the sea-fowl breeding on the freshwater cliffs" since the passing of the Act.

Report of the Committee on Standards of Electrical Resistance. The Committee consists of Prof. WILLIAMSON, *F.R.S.*, Prof. Sir CHARLES WHEATSTONE, *F.R.S.*, Prof. Sir W. THOMSON, *F.R.S.*, Prof. W. A. MILLER, *F.R.S.*, Dr. A. MATTHIESSEN, *F.R.S.*, Sir CHARLES BRIGHT, *C.E.*, *F.R.G.S.*, J. CLERK MAXWELL, *F.R.S.*, C. W. SIEMENS, *F.R.S.*, BALFOUR STEWART, *F.R.S.*, Dr. JOULE, *F.R.S.*, C. F. VARLEY, Prof. G. C. FOSTER, *F.R.S.*, C. HOCKIN, *M.D.*, *and* Prof. FLEEMING JENKIN, *F.R.S.* (Secretary).

THE Committee are unable to report any material progress during the last year in the work which remains to be done, and beg leave to suggest that this work may probably be more effectually expedited by the appointment of several small Committees than by retaining the large but somewhat cum-

brous organization by which their work was commenced. When the Committee was first appointed, no coherent system of units for the measurement of electrical resistance, currents, quantity, capacity, or electromotive force had met with general acceptance. The so-called absolute system existed indeed on paper, but in far too intangible a form to be either understood or used by practical men. At the same time, proposals for the adoption of isolated units, variously determined, had been carried out, with more or less success, so as to meet in some degree the immediate requirements of telegraphy. Many competing units of this nature were in the field. The Committee chose a system based on the absolute measure, and so, at least as far as electrical resistance was concerned, made this measurement a tangible and practical operation; and their choice has been ratified by men of science over a great portion of the globe. Copies of the unit of resistance adopted by the Committee in 1864 were deposited at the Kew Observatory; and others exist in the hands of electricians in various parts of the world. Comparisons of several of the copies, which were published in the Report of the Committee for 1867, showed that, with one or two exceptions, the ratio of their resistances remained unchanged. It is, however, desirable that additional comparisons should be made from time to time. Incidentally many researches of considerable value were carried out by the Members of the Committee; and the yearly reports have been so generally in request that it may be advisable to reprint the entire series.

No second unit, however, has been issued by the Committee, although apparatus for the determination of the units of capacity, quantity, potential, and intensity of current have been constructed, both with the funds of the Association and from the private means of its members. The great numbers of the Committee render meetings of rare occurrence; and the Subcommittees appointed to undertake the work have been lately remiss in its execution; the Committee, believing that direct responsibility to the Association and greater freedom of action will act as a stimulus to individual members, beg to suggest that the Electrical-Standards Committee be not reappointed, but that three new Committees of smaller numbers be chosen, to determine and issue:—1st, a condenser representing the unit of capacity; 2nd, a gauge for showing the unit difference of potential; 3rd, an electrodynamometer adapted to measure the intensity of currents in a decimal multiple of the absolute measure.

They would also suggest that it be an instruction to each Committee that it shall carry out the system adopted by the Electrical-Standards Committee, and that these new Committees shall have the use of all instruments hitherto constructed with the funds of the Association, a list of which is appended (in account book).

Considering that the principal instruments have already been constructed, the Committee believe that a small grant of, say, £20 to each Committee, will be sufficient to meet the expenses of the next year.

In conclusion, should this suggestion be adopted, they beg to recommend that a volume, containing the complete series of reports, be issued by the Association, and sold to the public, feeling assured, from the demand for isolated copies, that such an issue would involve no expense to the Association.

Sixth Report of the Committee for Exploring Kent's Cavern, Devonshire,—the Committee consisting of Sir CHARLES LYELL, *Bart., F.R.S.,* Professor PHILLIPS, *F.R.S.,* Sir JOHN LUBBOCK, *Bart., F.R.S.,* JOHN EVANS, *F.R.S.,* EDWARD VIVIAN, GEORGE BUSK, *F.R.S.,* WILLIAM BOYD DAWKINS, *F.R.S.,* WILLIAM AYSHFORD SANFORD, *F.G.S., and* WILLIAM PENGELLY, *F.R.S.* (Reporter).

DURING the year which has elapsed since the Association met at Exeter, the Committee have continued their researches without intermission, and have in all respects adhered to the method of exploration adopted at the commencement and described in detail in their First Report (Birmingham, 1865). The Superintendents have continued to visit the Cavern daily, and to send Monthly Reports of progress to Sir Charles Lyell, the Chairman of the Committee; the daily results have been regularly journalized; the workmen, George Smerdon and John Farr, have continued to give the most entire satisfaction; and the great interest felt in the investigations by visitors and residents in Torquay has undergone no abatement.

At the close of the last Meeting of the Association, a large number of the Members and Associates visited the Cavern, where they were received by one of the Superintendents, who conducted them through it and explained the most striking phenomena connected with it. In addition to this large party, the Cavern has, from time to time during the year, been inspected, under the guidance of the Superintendents, by Professor Stokes (President, British Association), the Duke of Somerset, Lord Talbot de Malahide, Lord H. Thynne, Sir H. Verney, Sir J. Kay Shuttleworth, Sir A. Malet, General Cotton, General Lefroy, General Tremenhere, Rev. Dr. Robinson, Rev. Prof. Maurice, Rev. O. Fisher, Rev. H. H. Winwood, and Messrs. W. R. A. Boyle, J. Dundas, A. Macmillan, E. B. Tawney, R. Valpy, W. Vicary, and A. R. Wallace, and many others.

The Committee have again the pleasure of reporting that they have been enabled to render assistance to those engaged in similar researches elsewhere. Sir J. Kay Shuttleworth, Chairman of the Committee who have recently undertaken to explore the caves in the Mountain-Limestone near Settle, in Yorkshire, opened a correspondence with the Superintendents of the work in Kent's Cavern, which eventuated in an arrangement that Mr. Jackson, Superintendent of the Yorkshire investigations, should visit Devonshire for the purpose of making himself fully acquainted with the mode of operation carried out there. Accordingly, on March 1, 1870, he reached Torquay, where every facility was given him by the Superintendents and the workmen for familiarizing himself with the work in all its details.

It has been stated in previous Reports:—that Kent's Cavern consists of an Eastern and a Western Division, each composed of a series of chambers and galleries; that it has two Entrances, which are about 50 feet apart, 200 feet above the mean sea-level, from 60 to 70 feet above the bottom of the valley in the same vertical plane, situated in one and the same low vertical cliff in the eastern side of the hill, and which open at once into different branches of the Eastern Division; and that the labours of the Committee have been restricted to the Eastern Division, the different branches of which were known as the North-east Gallery, the Vestibule or Sloping Chamber, the Gallery, the Lecture Hall, the South-west Chamber, the Water Gallery, and the North and South Sally-ports. In their Fifth Report (Exeter, 1869) the Committee stated that, with the exception of the last two, the exploration of the entire series had been completed to the depth of 4 feet below the stalagmitic floor,

without, however, reaching the bottom of the cavern; and that some progress had been made in the South Sally-port.

The Sally-ports were so named by the late Rev. J. M'Enery, who firmly believed that if excavated they would be found to lead to new external openings in the eastern slope of the hill, through which, indeed, burrowing animals, especially foxes, had found ready access to the body of the cavern. The year which has elapsed since the Fifth Report was presented has been spent in the exploration of these branches and their ramifications, the characters and contents of which are to be the subjects of the present Report.

The South Sally-port.—The entrance of the South Sally-port is in the eastern wall of the Lecture Hall. It is about 10 feet wide, 80 feet west and 52 feet south of the Arched or Southern Entrance of the cavern. Its direction is, on the whole, towards the south-east; and with its ramifications it occupies a space of about 80 feet from east to west, and 40 feet from north to south. Its width, however, varies from 21 to 2 feet, and averages about 10 feet. There is not the least indication that it leads to an external opening, or that any animals ever found or formed a passage into it from the exterior. Indeed, its direction is not such as to take it to the hill-side.

Before the Committee commenced their operations in it, the height of its roof above the deposits at the entrance was about 4 feet. At 45 feet in the interior this had so diminished as to render it necessary to excavate to the depth of 5 feet, instead of the customary 4 feet, in order to secure sufficient height for the workmen; and through nearly 30 feet before reaching the inner end the deposits and roof were in contact.

At the entrance, and for some distance within it, the roof and walls bore no indications of either the corrosive or erosive action of water, the edges of the beds of limestone being everywhere sharp and angular. Beyond this they assumed a corroded or fretted aspect; and still further in, the roof had the appearance of a fissure, in which the walls gradually approach at higher and higher levels, and a large mass of limestone threatens to fall at no very distant future; indeed a block of great size, which had fallen over the entrance in what may be called comparatively very recent times, gave the workmen a great amount of labour in blasting and removing it. It is probable that the sharp, angular character of the roof and walls at this part, already mentioned, is due to the recent severance of this mass. It may be doubted whether the fissure-like character of the roof just spoken of is any thing more than one of the "joints" so common in all the palæozoic rocks of Devonshire and Cornwall, which has been slowly widened by the action of acidulated water percolating through it. At and near this part the walls are much corroded, and not unfrequently fretted into holes rudely resembling the so-called *lithodomous perforations* met with in limestone rocks in various localities, and which have been recently much discussed. Beyond the "fissure" there are several conical holes in the roof, which, as they ascend, rapidly diminish in size. Most of them are more or less tortuous, thereby rendering it impossible to say whether they pass upwards to the surface of the hill in the form of "swallets" or Swallow-holes. Some of them are lined with stalagmitic matter, whilst others, showing the naked limestone, have a very decided water-worn aspect. A few of both kinds have faint traces of reddish soil or loam, whilst others are perfectly clean. Near the inner end of this branch of the cavern the walls in several places indicate the long-continued erosive action of water.

A floor of granular stalagmite, varying from 21 inches to 1 inch in thickness, extended from the entrance to about 15 feet within it. Beyond this

there was no trace of any thing of the kind until reaching 27 feet, where small patches presented themselves at considerable intervals. At length they became more numerous and decided; and at 50 feet there was a continuous floor from wall to wall, varying from 1 inch to upwards of 2 feet in thickness, and extending, without interruption, to the end. It is perhaps worthy of remark that, from its entrance to upwards of 40 feet within it, the South Sally-port is remarkably dry at all seasons, but that beyond this area it is greatly exposed to drip. There is no doubt that the stalagmitic floor at its entrance was formed of calcareous matter which had not been furnished by or through the surrounding roof or walls, but had flowed in from the adjacent Lecture Hall. In short, here, as everywhere else in the cavern, the presence or absence of a deposit of stalagmite is a trustworthy indication that the locality is at present wet or dry respectively.

On the stalagmite at the entrance there was a layer of black mould, differing from that found in the same position in other branches of the cavern in containing an admixture of the typical red cave-earth, which became more and more abundant further and further in, until, at about 30 feet from the entrance, the deposit was exclusively cave-earth from top to bottom of each section. At 50 feet from the entrance, where the inner stalagmitic floor began, the following was the succession of deposits in descending order:—

First. Red cave-earth, from 12 to 21 inches thick.

Second. Granular stalagmitic floor, from 1 to 24 inches.

Third, or lowest known. Cave-earth of unknown depth, but exceeding 5 feet.

The cave-earth was commonly of the ordinary character—a mixture of red loam and angular pieces of limestone in about equal quantities. Occasionally subangular and well-rounded pieces of red grit were found in it; and it everywhere contained blocks of stalagmite, sometimes of considerable size, which cannot but be regarded as remnants of a floor older than that overlying the deposit in which they were incorporated, and which had been destroyed by some natural agency. From the entrance to 45 feet from it, there were also in the cave-earth numerous large masses of limestone, several of which required to be blasted in order to their removal. In some instances they projected upwards through the deposit and the overlying stalagmite; and in one case a block so interrupted the continuity of the latter as to leave a passage, under the block itself, into the deposit beneath, of which it was obvious that some burrowing animal had availed itself. No such masses were found beyond the 45 feet just mentioned.

From the entrance to 60 feet within it, the cave-earth was traversed by a tunnel or tunnels, running, on the whole, longitudinally and horizontally, with an occasional bifurcation. In most cases they were adjacent to one of the walls of the cavern or to one of the large fallen masses of limestone just mentioned; but occasionally they passed entirely through the earthy deposit, when their vertical transverse sections were either circular or elliptical, and varied from 6 inches to 2 feet in diameter. Their sides and roof were tolerably smooth, but less so than their floors, which were firmly compacted and somewhat blackened, as if by frequent passing. Careful attention was given to the subject; but very few objects were found in them, the most important, besides those mentioned in the Fifth Report, being a canine of *Felis spelæa*, and an accumulation of dry moss, probably the nest of some animal. There were no tunnels in the innermost 20 feet of this Sally-port.

At 34 feet from the entrance and for some distance beyond, the deposit, below the third foot-level, adjacent to the south wall of the cavern consisted

of materials closely resembling those which composed the rock-like breccia below the old crystalline stalagmitic floor in the South-west Chamber and the Water Gallery, described in the Fourth and Fifth Reports (Norwich and Exeter, 1868 and 1869), but differing from it in being quite incoherent and destitute of fossils, whilst the typical cave-earth, at the same level and adjacent to the opposite wall (a distance of a very few feet at most), yielded the usual complement and variety of specimens.

From 57 to 60 feet from the entrance, the deposit below the second foot-level contained no stones of any kind, and consisted of very fine firmly compacted earth, having very few fossils.

At 38 feet from the entrance, where there was no stalagmitic floor, there was a thin band of charcoal about 3 feet long and 2 feet broad, 10 inches below the surface, and midway in the section, so as to leave interspaces of upwards of 3 feet between its ends and the walls of the cavern.

The upper surface of the deposits was an inclined plane dipping towards the inner end, where it was 10·5 feet lower than at the entrance, whilst the latter was 13 feet lower than the surface of the cave-earth at the Arched or Southern Entrance of the cavern, at which the Committee commenced their investigations. Indeed the extremity of the South Sally-port is at once the most southerly and the lowest point of the cavern which has at present been reached.

Besides a large number of bones (including several of birds and a few of fish) and portions of antlers, the South Sally-port yielded about 1400 teeth and identifiable fragments of teeth, some of which were in jaws or portions of jaws. The entire series may be thus distributed:—

	per cent.		per cent.
Horse	29	Deer, including Reindeer and "Irish Elk"	2
Hyæna	27	Lion	2
Rhinoceros	11	Ox	1
Bear	8	Wolf	
Sheep	7	Hare	
Badger	3	Dog (?)	each less than 1
Fox	3	Pig	
Rabbit	3		
Elephant	2		

In the Table the arrangement is throughout that of descending order. Thus the teeth of Badger, Fox, and Rabbit formed about 3 per cent. each of the entire series; but the first were rather more, and the third rather less, abundant than the second, and so on in other cases. The same arrangement will be observed when describing the other Sally-port and the passages connected with it.

From the disturbed state of the deposits in this branch of the cavern, the Committee were prepared for the commingling of bones and teeth having a modern aspect with those bearing all the indications of antiquity. Accordingly some remains of the principal extinct Cave-mammals were found in the deposit above the stalagmitic floor where this existed, and on the surface where it did not; and, in like manner, though very few remains were found in the tunnels, a tooth of Hog was found 2 feet deep in the cave-earth, and skulls, jaws, and teeth of Sheep were met with somewhat frequently at all depths. As has been already stated, the tunnels ceased at about 60 feet from the entrance; and there also ceased the inosculation of ancient and modern relics; the latest recorded case of Sheep below the sta-

lagmite was one tooth, in the first foot-level, at 62 feet from the entrance; and beyond this point there was no instance of any part of an extinct mammal above the floor. Agglutinated lumps of Beetles' wings and wing-cases were met with at all levels within the disturbed area.

The specimens found in the stalagmitic floor, though but few, were of considerable interest. Amongst them were teeth of Bear, Elephant, Hyæna, and Rhinoceros, and a portion of the internal shell of a Cuttlefish (*Sepia officinalis*), thus confirming the statements made by the Committee in previous Reports, that at least some of the extinct Cave-mammals outlived the period represented by the cave-earth *.

As elsewhere in the cavern, some of the bones of the extinct mammals were gnawed, some were greatly discoloured, and some, irrespective of the level they occupied, were invested with films of stalagmite.

Some localities were rich, whilst others were poor in specimens. Occasionally they were found almost exclusively against one wall of the cavern, whilst in other instances their distribution was tolerably uniform. They continued to present themselves in the higher levels after they had ceased to do so in the lower ones; thus in the fifth or lowest foot-level there were none beyond 51 feet from the entrance; in the fourth they continued up to 59 feet, and a solitary Hyæna's tooth was found 17 feet beyond this; in the third level they were met with in tolerable abundance as far as 60 feet, and a tooth of Rhinoceros with a fragment of bone appeared at 65 feet; the last specimen in the second level occurred at 73 feet, and in the first at 76 feet. Nothing was found in the last 4 feet.

In this branch of the cavern twenty-one flint implements and flakes were found, of which ten were mentioned and four briefly described in the Fifth Report (Exeter, 1869). Of those which have recently been discovered, four only require special notice. No. 4561 was found on September 11, 1869, at 55 feet from the entrance, with a tooth of Horse, a tooth of Rhinoceros, and a coprolite, in the fourth foot-level of cave-earth, over which was a stalagmitic floor 14 inches thick. It is of white flint, lanceolate in form, strongly carinated on one side, and slightly concave longitudinally on the other, which is crowded with facets, indicating the dislodgment of small flakes in great numbers. It measures 4·4 inches long, 1·1 inch wide, and ·3 inch thick at its broader end, and tapers gradually towards its point, which it has unfortunately lost. It is the best implement of its type which the cavern has yielded. No. 4521 is of the same kind, and also of white flint, but less delicate in its proportions, being 3·1 inches long, 1·1 inch broad, and ·4 inch thick at the butt end. It was found with a jaw of Rabbit, a tooth of Horse, a tooth of Rhinoceros, and fragments of bone, on September 6th, 1869, at 53 feet from the entrance, in the third foot-level of undisturbed cave-earth, over which was a stalagmitic floor 2 feet thick. No. $\frac{2}{4526}$ is probably a rude core, and is noteworthy only on account of its colour. It is a portion of a nodule, the outer surface being of a very dull pink which extends to the depth of stout wrapping-paper; beneath this is a bluish inky band about twice this thickness, within which the colour is a creamy white with drab patches. It was found on the same day and in the same "parallel" as the specimen last described, and in the foot-level next below. There were lying with it a tooth of Elephant, three teeth of Horse, four of Hyæna, and a wedge-shaped flake of white flint (No. $\frac{1}{4526}$). No. 4626 is a well-formed flake of apparently the same kind of flint as $\frac{2}{4526}$; but its

* See especially Report of the Thirty-ninth Meeting of the British Association, Exeter, 1869, p. 204.

inky band is from ·2 to ·3 inch broad. It was found, with a tooth of Horse, bones, and a coprolite, on October 2nd, 1869, at 63 feet from the entrance, above the stalagmitic floor.

The two specimens last described are in their colours unlike any other flint implements, or flakes, or cores found in the cavern. Specimens white on the surface and dark in the interior are very common; but in those under notice the succession is reversed.

Amongst the remains of animals there is part of an antler of the Reindeer (No. $\frac{1}{4604}$), which has been gnawed. One of the grooves or scores on it, however, is unusually deep and extends almost completely round it, being interrupted at two opposite points only. It is so utterly without a parallel amongst the multitude of gnawed bones which have been found in the cavern, that it seems less unreasonable to ascribe it to human agency than to the teeth of any animal. It was found, with a tooth of Horse, bones and bone-fragments, and a coprolite, on September 23rd, 1869, at 59 feet from the entrance, in the third foot-level of cave-earth, and beneath a floor of stalagmite 16 inches thick.

The exploration of the South Sally-port absorbed nearly six months, and was completed on November 12, 1869.

The North Sally-port.—The entrance of the North Sally-port is in the east wall of the Great Chamber, 28 feet south and 42 feet west of the Arched Entrance of the cavern. All that was known about it when the Committee commenced its exploration was, that it was a rude tunnel about 27 feet long, and at its entrance 8 feet high and 6 feet wide, having a rugged floor of stalagmite more or less interrupted by large and small masses of limestone, and rapidly descending from the mouth to the inner end, where it was about 3 feet wide, having the floor and roof in contact, with the exception of a small aperture on the right, and a slightly larger one on the left, which suggested that on being excavated it might prove to be of greater length and to bifurcate. It is now known to be a low labyrinthine passage, varying from 1·5 to 9 feet in breadth, but rarely exceeding 3 or, at most, 4 feet, ramifying very tortuously, and with sundry bifurcations and transverse passages, through an area measuring about 86 feet from north to south, and 84 feet from east to west, and terminating in an external opening in the eastern slope of the hill, in the same vertical plane as the well and long-known Arched or Southern Entrance of the cavern, but about 18 feet below it, and 10 feet further eastward.

The North Sally-port, then, *has* an *external* as well as an *internal* mouth or entrance. The former, that just discovered, is nearly due east from the latter, and by the least circuitous route is upwards of 140 feet from it. Excursions, however, may be made in various other directions; and, indeed, one or two of what are supposed to be minor branches remain to be excavated. In one part, nearer to its internal than to its external mouth, the labyrinthine passages have cut the limestone rock into three insular masses, known as the "Islands."

Up to 20 feet from the internal entrance the excavation was limited to a depth of 4 feet below the base of the stalagmitic floor, as in the other branches of the cavern generally; but beyond this point it was found necessary to sink to 5, and in some places 6 feet, on account of the lowness of the roof; and even now those who traverse the various passages have to be careful in their movements, so as to avoid collision with the various projections and pendants.

In what may be termed the first "reach" of the Sally-port, that which

has always been accessible, the roof and walls are much fretted, except certain portions of the southern side, which are clothed with heavy masses of stalagmitic matter. The passage on the north-west of the "Islands" has the aspect of a water-course whose roof and walls have subsequently been much fretted, and in some places corroded into holes, perhaps less rudely resembling "lithodomous perforations" than those in the South Sally-port, which have been already mentioned. Between the "Islands" and the external entrance, indications that the passages are deserted water-courses frequently present themselves, and "swallets" occur in the roof at various places—some lined with stalagmite, some naked, some slightly stained with soil, and some perfectly clean.

A floor of stalagmite of granular structure, which in many cases was so charged with fragments of limestone as to be a concrete extremely difficult to break up, extended continuously from the internal entrance to 14 feet within it, and in some instances attained the thickness of 33 inches. Thence to 16 feet it thinned out before quite reaching the north-eastern or left wall, after which it was again continuous to the end of the first "reach," where it was in contact with the roof and was 12 inches thick. Beyond this the stalagmite was very partial, rarely extended quite across the passages, and more frequently than otherwise there was no trace of it. In the passage on the south-western side of the two principal "islands," as well as in the narrow "strait" which divides them, there were two more or less continuous floors, one over the other, with an interspace of from 5 to 20 inches. In various places there were, adhering sometimes to one wall only and sometimes to both, rude moulding-like fragments of a floor which had been destroyed.

From the Internal Entrance, through the entire length of the first "reach" and 8 feet inwards in the second, but in no instance beyond, a black deposit (the true "black-mould" of previous Reports), varying from 10 to 20 inches in depth, lay everywhere on the stalagmitic floor, where the latter existed, and on the cave-earth (next to be described) where it did not, its junction with the latter being sharply defined. Beyond the end of the first "reach" the upper surface of the "black mould" approached the roof to within at most 10 or 14 inches.

The deposit next below the stalagmitic floor was the red cave-earth, being of the typical character to the depth of at least 2 feet, below which it frequently consisted of loam of darker red and subangular pieces of grit of the same colour—the materials of the *breccia* rather than of the cave-earth. In every passage and at all levels there were incorporated in the cave-earth fragments of stalagmite, varying in volume from a cubic inch to 10 cubic feet. There were also, but in less abundance, well-rolled fragments of rock not derivable from the cavern-hill. Amongst the latter was a portion of a yellowish drab pebble of fine-grained grit or quartzite, which had obviously been broken and subsequently rolled. This specimen was met with about 5 feet within the new or External Entrance.

At 19 feet from the Internal Entrance, a tunnel was found in the fourth foot-level of the cave-earth, adjacent to the north-east wall; and at 22 feet another was broken into on the opposite side. A transverse vertical section of the latter was a semiellipse, measuring 18 inches in breadth at the floor, and the same in height, whilst another section of it, a few feet further in, measured 33 and 24 inches respectively. That on the opposite side was not quite so large. They were both continued through the remainder of the first "reach" and to about 6 feet in the second, where they ended. Their depth below the surface was tolerably uniform throughout; but they were not

always adjacent to the walls of the cavern. Nothing of the kind was found again, except at about 30 feet beyond the point just specified, where a small one, about 2 feet long, was laid open. In this branch of the cavern the tunnels had the aspect of water-courses rather than of burrows. Occasionally bones and pieces of limestone projected from their sides; and it was observed that the exposed portions of the latter had always the blanched appearance of such stones when found in shallow soil on limestone and beneath a thin covering of turf, whilst their remaining portions were of the same colour as the deposit in which they were lodged. No modern bones or other objects were found in the tunnels.

The upper surface of the cave-earth at the internal mouth of the North Sally-port was 5·5 feet below that at the Arched Entrance of the cavern; thence to the external entrance, by the most direct route, it formed three inclined planes,—of which the first fell 16 feet, towards the exterior of the hill (*i. e.* eastward), in a length of 67 feet—the fall, however, being by no means uniform in amount. In the second plane the dip was reversed, and the workmen in their excavations ascended 8·5 feet in a length of about 45 feet; after which the dip towards the exterior was resumed, and continued to the new mouth, giving a fall of 5 feet on reaching it. Hence the surface of the deposit at the external entrance was 12·5 feet lower than at the internal, and 18 feet lower than at the Arched Entrance of the cavern.

The branch of the cavern now under notice contained very large quantities of bones and other remains of animals.

So long as it presented itself, the overlying black mould yielded potsherds, marine shells (including *Cardium*, *Pecten*, and the internal shell of Cuttle-fish), and bones (chiefly modern, but a few of extinct animals—the astragalus of Rhinoceros being the most important of the latter).

In one instance only, about 26 feet before reaching the external entrance, did any bones occur in the stalagmitic floor; and these were few and, in themselves, unimportant.

The distribution of the fossils in the cave-earth was very irregular. The first four " foot-parallels " contained no specimens of any kind. Nothing was found in the second foot-level until reaching 7 feet from the entrance, and nothing in the first until the excavation had reached 11 feet; after which fossils were met with in tolerable abundance in every parallel, and almost in every level, as far as 33 feet, even where local peculiarities made it necessary to excavate to the depth of 6 feet.

Perhaps their irregular distribution was nowhere more strongly marked than in the various passages connected with the " islands," commencing at the point just specified—33 feet from the entrance. Along the entire north-western passage fossils were very abundant, culminating probably on January 19th, 1870, when two " yards " of cave-earth lying one on another (in other words, a parallelopiped of the deposit measuring 3 feet long, 2 feet deep, and 1 broad, and therefore containing 6 cubic feet of matter) yielded 51 teeth of Hyæna, 45 of Horse, 27 of Rhinoceros, 8 of Deer, 3 of Elephant, and 1 of Wolf, 4 astragali of Rhinoceros, 3 portions of antlers, and a huge assemblage of bones and fragments of bones. Along the northern and north-eastern sides of the " islands " they became less numerous, especially in the third foot-level. On the east there were none in the lowest two foot-levels. On the south 320 cubic feet of deposit was found to contain no more than four specimens. The low passage terminating at the south-west angle of the " islands," and in which the deposits very nearly reached the roof, opened into one of much greater height, in which the cave-earth was covered with

a stalagmitic floor 4 inches thick. In this floor, almost at the commencement of the passage, there was a rudely circular hole, about 18 inches in diameter. One of the Superintendents, who was present when this was disclosed, drew himself up through the opening so as to command a view of the space above, when he found, mixed with a small amount of cave-earth, a vast accumulation of bones and teeth, some of which were partially imbedded in the stalagmite. Above this mass of remains was, as has been already stated, another floor of stalagmite, the space between the two being at that point about 20 inches in height. The workmen proceeded to break up both floors; and the labour was rewarded by the immediate exhumation of 29 teeth of Hyæna, 21 of Elephant, 21 of Horse, 18 of Rhinoceros, 7 of Deer, including the "Irish Elk," 2 of Dog (?), 1 of Bear, and such a heap of bones and bone-fragments as to render it necessary to send for a cart for the removal of the "find." The upper floor was about 6 inches thick, and had a considerable space above it, in which there were neither fossils nor deposit. The two floors (the upper one being partially destroyed), with their rich intermediate layer of bones and cave-earth, extended along the entire passage on the south-western side of the "islands," and through the "strait" separating the two largest of them. In short, the fossil treasures there were a continuation of those which had previously been met with on the north-west. Nothing was found in the deposit beneath the lower floor.

In a considerable recess on the south-east of the "islands," out of which not less than 280 cubic feet of matter was dug, the only things found were a very few bones of birds. In the passages leading from the north-eastern angle of the "islands," fossils were, with a few exceptions, tolerably abundant, but were most prevalent in the upper levels.

Of teeth alone, the North Sally-port yielded at least 2600, belonging to the animals and in the proportions stated below:—

	per cent.		per cent.
Hyæna	31	Lion	2
Horse	31	Bear	1
Rhinoceros	16	Fox, Beaver, Wolf, Dog (?), Cat, Sheep	each less than 1
Deer, including "Irish Elk" and Reindeer	6		
Badger	4		
Rabbit	2		
Elephant	2		
Ox	2		

Amongst the peculiarities of this branch of the cavern are the comparatively large numbers of remains of Badger, Elephant, and Beaver—and, when compared with those in the other Sally-port, the small number of Sheep, of which the only remnant was one tooth.

The teeth of Elephant are not only relatively more numerous, but some of them exceed in size any that have been found elsewhere in the cavern; and the plates of a few of them are remarkably thick.

The number of Beavers' teeth is eight:—three molars in part of a jaw (No. 4789) found December 20, 1869, with two teeth of Horse, in the first foot-level of cave-earth; a loose molar (No. $\frac{1}{4801}$), found the next day, in the same level and the adjoining foot-parallel; and an almost perfect left lower jaw (No. $\frac{8}{5080}$) with three molars and the fang of the incisor *in situ*, found on May 3, 1870, in the fourth foot-level, upwards of 50 feet from the former specimens.

Many of the bones are gnawed, some are more or less covered with films of stalagmite, some are greatly discoloured, and a few have the aspect of the remains found in the breccia beneath the old crystalline floor of stalagmite described in previous Reports.

Taken as a whole, the osseous remains found since the Fifth Report (1869) was presented are probably superior to those found in any former year.

Instances of the commingling of ancient and recent remains occurred in the North as well as in the South Sally-port, but they were by no means so abundant in the former as in the latter.

In the branch of the cavern now under notice there were found seven flint implements and flakes, of which one was in the black mould overlying the stalagmite, one was in the first foot-level of cave-earth, two were in the second, two in the third, and one in the fourth foot-level. Three appear to have been struck from common flint nodules, and are comparatively unimportant. The remaining four are good specimens, but one of them only (No. 5124) needs description. It is ovate, worked to an edge all round its perimeter, 2·7 inches long, 1·6 inch in greatest breadth, and ·3 inch in greatest thickness. The bulb of percussion is well displayed on the inner surface, which is concave in every direction, but especially in that of its greatest axis. The outer surface is convex, or, rather, is formed of a series of distinct approximately plane surfaces, which concur to give it a considerable convexity. There are indications of a great amount of work along the entire margin on its outer face. Its colour is a very light grey, inclining to white; but there are indications of a dark interior. It was found with a tooth of Hyæna, a tooth of Rhinoceros, bones, and balls of fæcal matter, May 24, 1870, in the first foot-level of cave-earth, about 40 feet from the external entrance.

Of the seven specimens, five were found nearer to the external than to the internal entrance, and one (No. 5165), a small but good specimen, was no more than 15 feet from it.

Two of the bones found in this branch of the cavern appear to have been cut artificially. The first (No. $\frac{1}{4808}$) was found December 22nd, 1869, with remains of Badger, Fox, Horse, Hyæna, Ox, and Rhinoceros, 24 feet from the internal entrance, in the fourth foot-level of cave-earth, over which was a continuous floor of stalagmite 12 inches thick.

The second (No. $\frac{3}{4933}$) was found about 47 feet from the same entrance, on January 24th, 1870, with remains of Elephant, Horse, Hyæna, and Rhinoceros, in the second foot-level of cave-earth, over which there was no stalagmite.

Of the fish-bones which have been found, one (No. 5036) appears to have been pointed and used as a pin or awl. It was met with on April 21st, 1870, in the second foot-level of cave-earth, which was not covered with stalagmite, rather nearer to the internal than the external entrance.

The exploration of the North Sally-port was begun on November 12th, 1869; and in something more than eight months the workmen had dug their way through it. The new entrance was reached on July 19th, 1870. There are, however, one or two of its ramifications which are not yet excavated, having been passed intentionally in the progress of the work. How far they extend is at present unknown.

The External Mouth of the North Sally-port.—Though the Superintendents have no doubt that the North Sally-port really has an external entrance, the workmen have not dug their way to the day at the so-called new mouth. The following is the evidence on the question:—During eight months the direction of excavation had on the whole been outwards, *i. e.* towards the

hill-side, which, from the ground-plan of the work and the contour of the hill itself, was obviously nearly reached. This was confirmed by the appearance of very fine rootlets, not through the roof, but horizontally in the deposit, which, as the work advanced, grew larger and larger until they became roots two inches in diameter. The deposit had always been bounded by limestone walls on each side, and by a roof of the same material, between which and the cave-earth the interspace, where any existed, never exceeded a few inches in height. On July the 19th, 1870, the workmen suddenly ceased to be able to find a wall on the right or outside, or a limestone roof above them; and at the same time, and as suddenly, they were unable to reach the upper surface of the deposit, which had also undergone a change of characters. The materials through which they had now to drive were, first, or lowest, a variety of the cave-earth, with remains of the ordinary Cave-mammals, above which was an accumulation of small angular pieces of limestone, with but little earth and no fossils, and more or less cemented into a very loose concrete with stalagmitic matter; and the roof, or that which supplied its place, was of the same character—materials, in short, which are found everywhere in the upper portions of the numerous limestone fissures of the district. At that moment they were, according to their measurements, in the same vertical plane as the Arched Entrance of the cavern, at a level of about 18 feet below it, and 10 feet outside. In other words, they had dug their way through the cavern into a talus of earth and stones lining the hill-side, and which, from its upper surface to that on which they stood, was 18 feet deep.

Two reasons prevented their attempting to break through this mass to the open day:—first, it would probably destroy the only road to the cavern; and second, the attempt seemed somewhat hazardous, as the material showed a great tendency to "cave in." It being necessary, however, to confirm or disprove the conclusion that they had found a new entrance, a tunnel was dug through the talus 12 feet long, varying from 4 to 8 feet wide, and having the limestone rock for its inner or left boundary. The result was the same throughout: the floor and lower portion of the right or outer wall was a variety of the cave-earth with the common Cavern specimens; and the upper portions of this wall, as well as the ceiling, consisted of the loose concrete already described, and which contained no fossils.

As there was nothing further to be gained, and the work seemed unsafe, the tunnel was discontinued, and no doubt remained that the workmen had emerged from the cavern, and, in cutting the tunnel, had been laying bare a portion of the limestone hill on the left. It may be of interest to remark that this limestone overhung about 2 feet, so as to afford a "shelter" to that extent.

The lower portion of the external talus has been spoken of above as *a variety of the cave-earth*. It was in fact a fine silt with scarcely a trace of the common red colour, and closely resembled material which, from time to time, had been found within the cavern. Amongst the remains found in it were 11 teeth of Bear, 7 of Horse, 5 of Hyæna, and 4 of Rhinoceros. The bones, of which there was a considerable number, were frequently broken, decayed, and discoloured.

With the animal-remains two implements and one flake of flint were found. Both of the former are of the usual white colour. One of them (No. 5236) is little more than the point of what was probably once a good implement; the other (No. 5222) is a good lanceolate implement, 2·5 inches long, 1 inch broad at the butt end, and ·2 inch in greatest thickness. It is strongly carinated on the outside, and has three longitudinal facets. It was found July 28, 1870. The flake (No. 5226) is yellowish, and apparently discoloured.

Smerdon's Passage.—The new mouth is the external entrance, not only of the North Sally-port, but also of a previously unsuspected passage or under-vaulting, which, so far as is at present known, varies from 4 to 10 feet in width, and extends in a north-westerly direction. It has received the name of "Smerdon's Passage." On abandoning the tunnel just spoken of, the workmen were directed to commence the exploration of this Passage; and at the end of last month (August 1870) they had advanced about 20 feet into it. The deposit it contains is the common typical cave-earth, having, here and there, a thin patch of stalagmite, but nothing like a continuous floor, and everywhere reaching the roof, or within a few inches of it. It contains a considerable number of pieces of limestone, none of which exceed 10 lbs. in weight, a few subangular and rounded pieces of red grit, and blocks of Old Stalagmite in abundance, some of which measure from 5 to 6 cubic feet.

Numerous bones and upwards of 700 teeth were found, the latter of which may be thus apportioned:—

	per cent.		per cent.
Hyæna	57	Deer, including "Irish Elk" and Reindeer	2
Horse	19	Elephant	1
Rhinoceros	12	Wolf, Lion, Dog (?) each less than	1
Badger	3		
Bear	2		
Fox	2		
Ox	2		

As in other parts of the cavern, some of the bones were gnawed, some discoloured, and some more or less covered with films of stalagmite. With them were found several agglutinated lumps of bones of very small animals*, coprolites, three limpet-shells, a bit of charcoal, and four good flint flakes.

Amongst the foregoing facts there are some on which it is difficult to abstain from speculation.

As has been already stated, the late Mr. M'Enery named the Sally-ports from a settled conviction that they led to external entrances in the hill-side. The facts on which he relied were, first, the direction in which they extended, and, second and chiefly, the tunnels, which he ascribed to burrowing animals. The first was obviously not very conclusive; for he could not but be aware that unless the so-called Sally-ports extended considerably beyond the point to which he could penetrate, and without much tortuosity—points on which no opinion could be formed—they must fall far short of the exterior.

With reference to the tunnels, even if ascribable to burrowing animals, it by no means followed that they were commenced at, or connected with, the exterior of the cavern; for as there were well-known spots in each of the branches in question where there was no stalagmitic floor, there was no difficulty in supposing the animals to have commenced their burrows in these unprotected localities, to have sunk more or less vertically in the deposit, and at a suitable depth to have proceeded horizontally. In the Fifth Report, mention was made of vertical shafts of this kind†; and that this was the actual mode of operation is now rendered still more probable by the fact that no tunnels occur at or near the inner end of either of the two branches‡.

* One of these lumps was found to contain upwards of 1200 bones.

† See Report Brit. Assoc. 1869, p. 203.

‡ The Committee are well aware that the cavern is still occasionally frequented by animals. In the Fifth Report they mentioned the annoyance which the visits of a rat had occasioned; bats are often seen flitting to and fro or suspended from the walls, and they sometimes make a meal on the candles; and in the summer considerable numbers of the

As has been stated in previous Reports, the Committee have long been familiar with the presence of blocks of stalagmite in the cave-earth, and have inferred from them that an ancient floor of the cavern had been broken up by natural agency before or during the introduction of the cave-earth. There seemed no difficulty in conceiving of a machinery by which such a floor might have been destroyed in the comparatively lofty chambers. For example, it was known that the deposit which the old floor had covered, and on which it had been formed, had been, in some parts of the cavern, partially dislodged, or had subsided so as to leave the floor unsupported; it was also known that blocks of limestone, some of them scores of tons in weight, had from time to time fallen from the roof; and it was not difficult to see that such blocks would break into fragments any such unsupported floor on which they might fall.

This, however, utterly fails to account for the destruction of the floor which once existed in at least some of the narrow passages of the North Sally-port. That such floors have been destroyed admits of no question, since, as has been already stated, remnants of them still adhere to the walls, to say nothing of their abundant fragments in the deposit below. That they were not destroyed by the fall of blocks of limestone is obvious from the facts that their remnants on the walls show that they were almost in contact with the roof even as it now exists, and that the roof itself presents no indications that such masses have been detached from them. This problem still awaits solution.

Many of the potsherds in the North Sally-port were found in the overlying black mould considerably beyond the point where man could have actually placed or lost them, though not perhaps beyond the point where he might have thrown them, if he could be supposed to have had a motive for doing so. It seems not improbable, however, that, being, as they were, on a highly inclined plane of very contracted width, their presence in the spots where they were found was due to a participation in a slow and gradual movement of the black mould downwards and inwards, in consequence of the frequent passage of small recent animals.

There is greater difficulty in accounting for the occurrence of keen-edged flint implements and flakes at and near the external mouth of the North Sally-port. There is every reason to believe that the cave-earth found in the successive chambers at the highest level of the cavern was introduced through the long-known North and South (or Triangular and Arched) Entrances; whence it seems to follow inevitably that at that time the bottom of the valley was but little below these entrances, and was therefore nearly 20 feet above the level of the opening just discovered. That the "implements" are of human origin there is every reason to believe; but it cannot be sup-

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Common Shrew are occasionally observed near the door and in the adjacent thicket. On December 8th, 1869, one of the Superintendents found the workmen in a state of excitement, caused, no doubt, by an unwelcome visit of some infra-human marauder. They had that morning taken to the cavern a pound of candles, of sixteen to the pound, and hung them in the accustomed place. On going to cut one of them, at 3 o'clock, it was found that twelve of the pound were missing, and the condition of the remnants of the wicks was such as to indicate cutting rather than gnawing. Hence it would have been concluded that the loss was due to a human thief, had it been possible for one to have entered the cavern without the knowledge of the workmen. On examination, one of the missing candles was found between some large loose stones beneath the nail on which they were hung, but no trace of teeth-marks could be found on it. Before the men left work the remnant of the pound had been taken, so that not a candle was left; but by what agency, remains unknown; for though a gin temptingly baited was set at the spot, it failed to aid in the solution of the problem.

posed that man placed them where they were found *under the foregoing conditions*; for the bottom of the valley being then far above the low-level entrance, the passages into which it immediately opens were probably inaccessible, and certainly not available for human resort. On the other hand, the hypothesis that the flints were washed there from the upper chambers appears to be entirely negatived by the fact that, though lodged in a deposit largely charged with stones, they are entirely unrolled and retain their keen edges. It may be added that very few, if any, of the bones found with them show any marks of abrasion, that the implements are more numerous at and near its external entrance than elsewhere in the Sally-port, and that no such phenomenon presented itselt at or near the end of the other Sally-port, which has no external mouth.

May not the following be the solution of the problem? The implements and animal-remains found at the new entrance and in the passages connected with it were deposited after it had been laid bare, and are chronologically separated from those in the high-level chambers by an amount of time sufficient to deepen the valley to the extent of 20 feet, but not sufficient to make any change in the fauna of the district, or in the character of the implements which its human dwellers employed.

Mr. Ayshford Sanford has continued his identification of the fossils during the past twelve months, and has examined a large number of them. The present state of his health has unfortunately prevented his sending in a Report.

Third Report of the Committee for the purpose of investigating the rate of Increase of Underground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by Professor Everett, *at the request of the Committee, consisting of* Sir William Thomson, *F.R.S.*, Sir Charles Lyell, *F.R.S.*, J. Clerk Maxwell, *F.R.S.*, Prof. Phillips, *F.R.S.*, G. J. Symons, *F.M.S.*, Dr. Balfour Stewart, *F.R.S.*, Prof. Ramsay, *F.R.S.*, A. Geikie, *F.R.S*, James Glaisher, *F.R.S.*, Rev. Dr. Graham, E. W. Binney, *F.R.S.*, George Maw, *F.G.S.*, W. Pengelly, *F.R.S.*, S. J. Mackie, *F.G.S.*, *and* Professor Everett, *D.C.L.* (Secretary).

Mr. G. J. Symons, whose observations, extending to a depth of 1100 feet in a well at Kentish Town, were reported at last Meeting, has since repeated his observations at several depths.

The first 210 feet of the well (which is 8 feet in diameter to the depth of 540 feet) are occupied by air; and in this portion of the well the second series of observations give temperatures exceeding those observed in the first series by from 2° to 5° F., the excess diminishing as the depth increases. The second series were taken in July and August, whereas the first series were taken in January. It is evident that in this portion of the well, in spite of the precautions taken to exclude atmospheric influences, by boarding over the well and erecting a hut over it, the temperature varies with the seasons, the variations being in the same direction as in the external air, but smaller, and diminishing as the depth increases, but still amounting to 2°·2 at the depth of 200 feet.

We can feel no certainty that even the mean annual temperature in this portion of the well represents the temperature in the solid ground. On the contrary, the mean temperature in the well at any depth is probably intermediate between the temperature of the solid ground at that depth and the mean temperature of the external air.

It is well that such observations should have been carefully made and recorded in this one instance, if only for the sake of warning; and they show that we cannot expect to attain the object for which the Committee has been appointed by observations in large shafts filled with air.

Mr. Symons has also repeated the observations at 250 feet (which is 40 feet under water), and at the depths of 600 feet, 750 feet, and every 50th foot from this to 1100 feet, the lowest point attainable, on account of the mud, which extends 200 feet lower. The differences from the results obtained last year are $+\cdot 2$, $-\cdot 3$, $-\cdot 4$, $-\cdot 2$, $-\cdot 2$, 0, $-\cdot 1$, $-\cdot 1$, 0; which upon the whole strongly confirm the correctness of the observations.

The temperature at 1100 feet is 69°·8, which, if we assume the mean temperature of the surface of the ground to be $\left\{\begin{matrix}50^\circ\\49^\circ\end{matrix}\right.$, gives a mean increase downwards of $\left\{\begin{matrix}\cdot 0180\\\cdot 0189\end{matrix}\right.$ of a degree Fahrenheit per foot, or 1° for $\left\{\begin{matrix}55\cdot 5\\52\cdot 9\end{matrix}\right.$ feet.

The curve in which temperature is the ordinate and depth the abscissa, exhibits considerable irregularities till we reach the depth of 650 feet, beyond which it is nearly a straight line, and represents an increase of ·0187 of a degree per foot.

The strata penetrated by the well to the depth to which our observations extend consist of clay, sand, chalk, and marl, besides flints. (See tabular list appended.)

Mr. Symons in his Report calls attention to the anomalous position of a column of water increasing in temperature and consequently diminishing in specific gravity downwards, and suggests the inquiry why the warmer and lighter portions do not ascend to the top. The proper reply seems to be that the diminution of specific gravity, amounting to less than 1 part in 50,000 per vertical foot, does not furnish sufficient force to overcome liquid adhesion, and the water is thus able to remain in unstable equilibrium.

Mr. Symons intends, during the remainder of the present year, verifying those of his observations which have not yet been repeated, and concludes his Report by remarking that it appears desirable to ascertain, by observations from year to year, whether the temperature at a given depth (say, 1000 feet) remains constant or is subject to minute changes periodical or otherwise—a suggestion which appears fully worthy of being carried out.

Mr. Wm. Bryham, Manager of Rose Bridge Colliery, Ince, near Wigan, has taken very valuable observations during the sinking of that Colliery, which is now the deepest excavation in Great Britain. The pricipal results have already been given, in a paper to the Royal Society, by Mr. Edward Hull, Director of the Geological Survey of Ireland, who had previously published some important contributions to our knowledge of underground temperature, and has now consented to become a member of this Committee. Some of the depths, however, have been remeasured since Mr. Hull's paper was read, and I am now enabled, through the kindness of Mr. Bryham, to furnish a rather more accurate report.

The temperatures observed and the depths at which they were taken are as follows:—

Depth in yards.	Temperature Fahrenheit.	Depth in yards.	Temperature Fahrenheit.
	°		°
161	(64½)	734	88½
200	(66)	745	89
558	78	761	90½
605	80	775	91½
630	83	783	92
663	85	800	93
671	86	806	93½
679	87	815	94

All these temperatures, except the first two, were observed during the sinking of the shaft, by drilling a hole with water to the depth of a yard in the solid strata at the bottom. A thermometer was then inserted, the hole was tightly plugged with clay so as to be air-tight, and was left undisturbed for half an hour, at the end of which time the thermometer was withdrawn and read—a mode of observation which appears well adapted to give reliable results. With respect to the temperatures at 161 and 200 yards* (which I have enclosed in brackets to indicate uncertainty), Mr. Bryham informs me that he has some doubt as to the correctness of the thermometer with which they were taken, and that they were not taken in the shaft at the time it was sunk, but in the seams at the depths named.

Assuming the surface-temperature to be 49°, we have, on the whole depth of 815 yards or 2445 feet, an increase of 45°, which is at the rate of ·0184 of a degree per foot, or a degree for every 54·3 feet.

On plotting the temperature curve, including the two observations marked as doubtful, we find that it naturally divides itself into four portions, which are approximately straight lines.

The most remarkable of these portions is the second from the top, extending from the depth of 161 yards to that of 605 yards. It embraces 1332 feet, and shows an increase of only 1° for every 86 feet.

The third portion, extending from the depth of 605 yards to that of 671 yards, covers only 198 feet, and shows an increase of 1° for every 33 feet.

The lowest portion extends from the depth of 671 yards to 815 yards. It covers 432 feet, and shows an increase of 1° in 54 feet.

The topmost portion will be affected by the assumption we make as to surface-temperature. Assuming this as 49°, it shows an increase of 1° in 31 feet.

It is interesting to compare the Rose Bridge observations with those previously made by Mr. Fairbairn at Astley Pit, Dukenfield, Cheshire, which have been described by Mr. Hull in 'The Coalfields of Great Britain,' and by Mr. Fairbairn himself in the British Association Report for 1861. The results have been thus summed up by Mr. Hull:—

"1. The first observation gives 51° as the invariable temperature throughout the year at the depth of 17 feet. Between 231 yards and 270 yards, the temperature was nearly uniform at 58·0. And the increase from the surface would be at the rate of 1° F. for 88 feet.

"2. Between 270 and 309 yards, the increase was at the rate of 1° for 62·4 feet.

* Further inquiry has shown that these two temperatures must be rejected, as the thermometer with which they were taken was afterwards found (by comparison with other thermometers) to be in error by some degrees. No note was taken of the amount of the error, and the thermometer itself is destroyed.

Assuming the surface-temperature as 49°, we have an average increase downwards of 1° in 57·7 feet for the first 558 yards, and of 1° in 48·2 feet for the remaining 257 yards.

"3. Between 309 and 419 yards, the increase was at the rate of 1° for 60 feet.

"4. Between 419 and 613 yards, the increase was at the rate of 1° for 86·91 feet.

"5. Between 613 and 685 yards, the increase was at the rate of 1° for 65·6 feet. . . . . . .

". . . . The result of the whole series of observations gives an increase of 1° for every 83·2 feet. . . . ."

Mr. Fairbairn's own summary is as follows:—"The amount of increase indicated in these experiments is from 51° to $57\frac{3}{4}$° as the depth increases from $5\frac{2}{3}$ yards to 231 yards, or an increase of 1° in 99 feet. But if we take the results which are more reliable, namely those between the depths of 231 and 685 yards, we have an increase of temperature from $57\frac{3}{4}$° to $75\frac{1}{2}$°, or $17\frac{3}{4}$° Fahrenheit—that is, a mean increase of 1° in 76·8 feet."

Mr. Fairbairn here by implication throws doubt on the alleged invariable temperature of 51° at the depth of 17 feet, a determination which in itself appears highly improbable, seeing that, at Greenwich, the thermometer whose bulb is buried at a depth of 25·6 feet, exhibits an annual range of 3°·2, while that at the depth of 12·8 feet exhibits a range of 9°. But even if we assume the mean surface-temperature to be 49°, we have still upon the whole depth an increase at the rate of 1° in 80 feet, as against 1° in 54·3 feet at Rose Bridge.

Mr. Fairbairn's paper gives also the results obtained at a second pit at Dukenfield, which agree with those in the first in showing an exceptionally slow rate of increase downwards. The temperatures at the depths of $167\frac{1}{2}$ yards and 467 yards were respectively 58° and $66\frac{1}{2}$°, showing a difference of $8\frac{1}{2}$° in $299\frac{1}{2}$ yards, which is at the rate of 1° in 106 feet. The increase from the surface down to $167\frac{1}{2}$ yards, assuming the surface-temperature as 49°, would be 9°, or 1° in 56 feet; and the mean rate of increase from the surface to the bottom would be 1° in 80 feet, the same as in the first pit.

A tabular list of the strata at Rose Bridge is appended to this Report. A full account of the strata at Dukenfield is given in Mr. Fairbairn's paper (British Association Report, 1861).

With strata so nearly similar, and in two neighbouring counties, we should scarcely have expected so much difference in the mean rates of increase downwards. In this respect Rose Bridge agrees well with the average of results obtained elsewhere. Dukenfield far surpasses all other deep mines or wells, so far as our present records extend, in slowness of increase.

This implies one of two things—either that the strata at Dukenfield afford unusual facilities for the transmission of heat, or that the isothermal surfaces at still greater depths dip down in the vicinity of Dukenfield.

Mr. Hull has called attention to a circumstance which favours the first of these explanations—the steepness of inclination of the Dukenfield strata. He argues, with much appearance of probability, that beds of very various character (sandstones, shales, clays, and coal), alternating with each other, must offer more resistance to the transmission of heat across than parallel to their planes of bedding, as Mr. Hopkins has shown that every sudden change of material is equivalent to an increase of resistance; and it is obvious that highly inclined strata furnish a path by which heat can travel obliquely upwards without being interrupted by these breaches of continuity.

To this suggestion of Mr. Hull's it may be added that inclined strata furnish great facilities for the convection of heat by the flow of water along the planes of junction. It appears likely that surface-water, by soaking

downwards in this direction, may exercise an important influence in assimilating the temperature at great depths to that which prevails near the surface. Mr. Hull's own statement of his views is given in the footnote below*.

Mr. M'Farlane has been prevented from continuing his observations near Glasgow during the past year by the press of business incident to the removal from the old to the new College.

Mr. F. Amery, Druid House, Ashburton, Devon, has taken some observations with one of the Committee's thermometers in the shaft of a mine which had been unused for a year and was nearly full of water. The shaft is 12 feet ×7 feet, and descends vertically for 350 feet, after which it slopes to the south at an angle of 50°, continuing to the depth of 620 feet. The water stood at 50 feet from the surface. Mr. Amery observed the temperature at every 50th foot of depth in the vertical portion, and found it to be 53° at all depths, except at 250 feet and 200 feet, where it was 53·4 and 53·2 respectively. A copper lode crosses the shaft at the depth of 250 feet; and it appears to be generally the case, in the Cornwall and Devonshire mines, that copper lodes exhibit high temperature—a circumstance which Prof. Phillips explains by the conformation of the strata, which is such as to cause water from greater depths to make its way obliquely upwards by following the course of the copper lodes.

The nearly constant temperature observed from the surface to the bottom of the shaft seems to indicate a large amount of convective circulation. In this respect small bores have a decided advantage.

Mr. G. A. Lebour has taken observations with our thermometers in several shafts and bores near Ridsdale, Northumberland, made for working coal and ironstone. Mr. Lebour does not report the temperatures observed, which he characterizes as discrepant and utterly valueless, owing, he believes, to the numerous water-bearing beds which they cut through, and the very varying temperature of these waters. Having now, however, found a dry bore, he hopes to make a useful series of observations next winter.

One of the Committee's thermometers has recently been sent to Mr. John Donaldson, C.E., Calcutta, who has expressed his desire to aid in scientific observation, and, being now engaged in examining for coal and iron under Government, is likely to render us effective service.

Shortly after the last Meeting of the Association, the Secretary of this Com-

* "Rose-Bridge Colliery occupies a position in the centre of a gently sloping trough, where the beds are nearly horizontal; they are terminated both on the west and east by large parallel faults which throw up the strata on either side. The Colliery is placed in what is known as 'the deep belt.'

"Dukenfield Colliery, on the other hand, is planted upon strata which are highly inclined. The beds of sandstone, shale, and coal rise and crop out to the eastward at angles varying from 30° to 35°. Now I think we may assume that strata consisting of sandstones, shales, clays, and coal alternating with each other are capable of conducting heat more rapidly along the planes of bedding than across them, different kinds of rock having, as Mr. Hopkins's experiments show, different conducting-powers. If this be so, we have an evident reason for the dissimilar results in the two cases before us. Assuming a constant supply of heat from the interior of the earth, it could only escape, in the case of Rose Bridge, *across* the planes of bedding, meeting in its progress upwards the resistance offered by strata of, in each case, varying conducting-powers. On the other hand, in the case of Dukenfield, the internal heat could travel along the steeply inclined strata themselves, and ultimately escape along the outcrop of the beds.

"I merely offer this as a suggestion explanatory of the results before us, and may be allowed to add that the strata at Monkwearmouth Colliery, the thermometrical observations at which correspond so closely with those obtained at Rose Bridge, are also in a position not much removed from the horizontal, which is some evidence in corroboration of the views here offered."—*Proc. Roy. Soc.* 1870, vol. xviii. p. 175.

mittee addressed a letter to Professor Henry, Secretary of the Smithsonian Institution, United States, requesting his cooperation in furthering the object which the Committee have in view, at the same time forwarding one of our protected thermometers.

In June of the present year, an answer was received from Professor Baird, Assistant Secretary in charge, to the effect that Professor Henry's ill health during the present season had prevented his communicating to us the result of his labours in response to this request.

The letter addressed to Prof. Henry made special reference to an artesian well of extraordinary depth, which was understood to be in course of sinking at St. Louis; and at the same time a letter was addressed and a special thermometer sent to Mr. C. W. Atkeson, the Superintendent of the work of boring at St. Louis. No reply has been received from Mr. Atkeson, who appears to have left St. Louis before the letter arrived; but letters have been received, through the Smithsonian Institution, from Dr. Chas. W. Stevens, Superintendent of the County Insane Asylum at St. Louis, this being the institution for whose uses the well was sunk, together with a very interesting newspaper cutting, consisting of Mr. Atkeson's report on the works. The boring of the well was commenced (at the bottom of a dug well 71½ feet deep) on the 31st of March, 1866, and was continued till the 9th of August, 1869, when the work was stopped at the enormous depth of 3843½ feet, exceeding by more than one half the depth of Dukenfield Colliery. The strata penetrated consisted in the aggregate of 63 feet of clay, 6 feet of coal, 360 feet of shales, 2725 feet of limestone, and 680 feet of sandstone.

A cast-iron tube of 11½ inches bore was first put down, reaching from the top and secured on the limestone at the bottom. This tube was then lined inside with a wooden tube, reducing the bore to 4½ inches. A 4½-inch drill was put down through this tube on the above-mentioned date. The bore was afterwards enlarged to 6 inches, and subsequently to 11½ inches to a depth of 131½ feet. A sheet-iron tube was then put down, extending from the top to this depth, and the bore below was enlarged, first to 6 and afterwards to 10 inches diameter, to the depth of 953 feet. A sheet-iron tube 79 feet long was then put down, which rests on the offset at the bottom of the 10-inch bore. The 4½-inch bore was then enlarged to 6 inches to the depth of 1022 feet, and a wrought-iron tube of 5 inches bore, weighing more than 6 tons, was put down, reaching from the top to and resting on the offset at the bottom of the 6-inch bore, thus securing the work to this depth, and reducing the bore to a convenient size to work in. The 4½-inch bore has been continued to the depth of 3843 feet 6 inches without further tubing.

At the depth of 3029 feet the first observation of temperature was taken, and the reading of the thermometer was 107° Fahr. This first observation is stated by Dr. Stevens to be specially worthy of confidence, as having been confirmed by several repetitions, or, rather, to use Dr. Stevens's own words, "this was the maximum of several trials." It was taken, as well as those that followed it, by means of a registering thermometer (kind not mentioned); but in answer to our inquiries Dr. Stevens states, upon the authority of the carpenter who attached the thermometer to the pole by which it was lowered, "that no means were taken to defend the bulb from pressure." In the absence of further information (and Mr. Atkeson himself has not yet spoken), we can place no reliance upon the temperature recorded, as the thermometer had to bear a pressure of three-fifths of a mile of water.

The temperatures registered at lower depths, the deepest being 800 feet lower, were all (strange to say) somewhat lower than this, a circumstance

which is all the more remarkable because the pressure (which tends to make the reading higher) must have increased with the depth. At the bottom, or rather at 3837 feet, being $6\frac{1}{2}$ feet from the bottom, the temperature indicated was 105°. Either of these results, taken apart from the other and compared with the surface-temperature, would give a result not improbable in itself. The mean temperature of the air at St. Louis appears to be about 53°. But it seems desirable to avoid publishing calculations till the data are better established.

Unfortunately the apparatus which was employed in boring has all been removed, after the insertion of two wooden plugs, with an iron screw at the upper end of each, one at the offset at a depth of 1022 feet, and the other at the offset at the depth of 953 feet, for the purpose of separating the fresh from the salt waters. These plugs were driven in with great force, and can only be withdrawn with the aid of a series of poles and other appliances, such as were used in the boring, which will be rather costly. The poles alone are estimated to cost $1152, or about £200. If the plugs were withdrawn (and according to Dr. Stevens there is nothing but the expense to prevent it), the whole well would be available for observation. The Committee will make every effort to prevent so rare an opportunity from being lost.

The Secretary has also been in correspondence with Messrs. Mather and Platt of Salford Iron-works, respecting a boring at Moscow, for which they have furnished machinery, and which is to be carried to the depth of 3000 feet. They refer to General Helmersen, of the Mining College, St. Petersburg, as the best authority to whom application can be made for particulars of the Moscow boring as to temperature &c. The Secretary has accordingly written to General Helmersen, endeavouring to interest him in the objects of the Committee, and offering to forward thermometers. No reply has yet been received.

An element which it is necessary to know with a view to the correct reduction of our observations, but which in many instances it is difficult to obtain by direct observation, is the mean annual temperature of the ground at or near the surface. Instances frequently occur in which the temperature at the depth of 200, 300, or it may be 500 feet is accurately known, while the temperature in the superincumbent strata can only be guessed at. This is the case at the Kentish-Town Well, and partially at Rose Bridge and Dukenfield Collieries.

It is very desirable that, in connexion with temperatures at great depths, there should in each locality be an accurate observation at a depth of from 50 to 100 feet. At such depths in the solid ground, before it has been disturbed by mining-operations, one observation suffices to give a good approximation to the mean temperature of many years. At depths of 2 or 3 feet it is necessary to observe once a week or so throughout a year in order to get the mean temperature at that depth for that year; and this may differ by a considerable amount from the mean of a series of years.

In the Report of the Scottish Meteorological Society for the quarter ending December 1862, there is a comparison of the mean temperature of the air with that of the soil at the depths of 3, 12, and 22 inches at four stations, from observations extending over five years; and in the Journal of the same Society for the quarter ending December 1865, there is a comparison of the temperature of drained and undrained land from one year's observations undertaken for this purpose at two stations, and including also a comparison with the temperature of the air. The mean temperature of the air for each day is in these comparisons assumed to be the simple arithmetical mean of

the maximum and minimum, as indicated by self-registering thermometers 4 feet from the ground. From these observations it appears that the mean annual temperature of the soil was in every case rather above that of the air, and that the excess was greater for sand than for undrained clay, and was greater for drained land than for the same land undrained.

The greatest excess occurred in the case of the 22-inch thermometer at Nookton (Vale of Leven), where both surface and subsoil are sandy and dry. The five-yearly means at this station were:—

Air 46·1; soil at 3 inches 46·3, at 12 inches 47·3, at 22 inches 48·0, giving an excess of 1·9 for the temperature at the depth of 22 inches as compared with air.

The smallest excess, in the case of the 22-inch thermometers observed for five years, was at Linton (East Lothian), where it amounted to 0·7; but the observations on the effect of drainage gave for the year of observation an excess of only 0·2 at the depth of 30 inches in light sandy but undrained soil, under a rye-grass crop, at Otter House, near Loch Fyne the corresponding excess for drained land of the same kind and in the immediate vicinity being 0·9.

The mean temperature, at the depth of 3 feet, at Professor Forbes's three stations at Edinburgh, from five years' observations, gave an excess of 0·55 above the mean temperature of the air at Edinburgh as determined by Mr. Adie's observations.

Observations on soil temperature in England are much needed; but the Greenwich observations give an excess of soil above air temperature falling within the limits above quoted, the excess at 3 French feet being 1·7, while at 24 French feet it is reduced to 1°. The soil of which the Observatory Hill is composed, and in which the thermometers are sunk, is dry gravel, and the unusual circumstance of decrease of temperature downward observed in the comparison of the 3-feet and 24-feet thermometers, seems to indicate that the surface of the hill is warmer than the surrounding land.

In the present state of our knowledge, then, it appears that when the temperature of the earth has been observed at a depth of some hundreds of feet in any locality in Great Britain, and has not been accurately determined at a less depth, some knowledge of the rate of increase downwards may be obtained by assuming provisionally that the mean temperature of the surface is about a degree higher than the mean temperature of the air, supposing the latter to be known.

It is to be wished that the Meteorological Society would, from the ample materials in their possession, publish a map of annual isothermals for Great Britain; and the objects of this Committee would be greatly furthered by an extensive series of soil-temperature observations at the depth of about 3 feet.

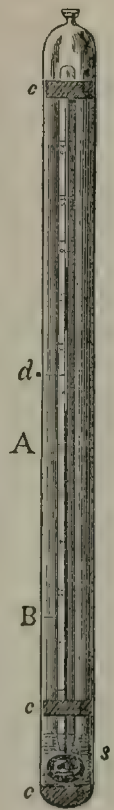
The Committee are anxious to carry into effect Mr. Hull's proposal (quoted in their last Report) to bore down from the bottom of a deep mine; and as Rose-Bridge Colliery appears to be an eminently suitable locality for such an operation, the Secretary has consulted Mr. Bryham respecting its practicability and probable cost. Mr. Bryham's reply is that there would be no difficulty in carrying out the proposal at Rose Bridge, that to make preparations and bore 300 feet would, on a rough estimate, cost £150, and that the second 300 feet would probably cost about the same sum.

The Committee would earnestly appeal to the liberality of the Association to enable them to put this design in execution; and they would remark that the sooner it is carried out, the more valuable the results obtained will be, as

the mine has been but recently opened to its present depth, and the influence of atmospheric temperature will every year become more sensible in the strata below.

The annexed figure represents the protected maximum thermometer, designed by Sir W. Thomson for the purposes of the Committee.

A is the protecting case of glass hermetically sealed, B the Phillips's thermometer enclosed in it and supported by three pieces of cork, *c*, *c*, *c*. A small quantity of spirit, *s*, occupies the lower part of the case, the remainder of the space being filled with air, and *d* is the air-bubble characteristic of Phillips's thermometer. The detached column of mercury above *d* remains suspended by adhesion in spite of moderate shaking. The instrument has been found to register correctly even under a pressure of $2\frac{1}{2}$ tons to the square inch.



Section of Strata sunk through (with shaft 16 feet diameter) at Rose-Bridge Collieries, Ince, near Wigan.

No. on Sect.	Description of Strata.	Thickness.	No. on Sect.	Description of Strata.	Thickness.
		yds. ft. in.			yds. ft. in.
1.	Outset	9 0 0		Brought forward	53 0 11
2.	Soil	0 1 0	13.	Strong linn and wool	2 1 0
	Clay	1 0 0	14.	Dark blue shale	7 2 5
3.	Strong marl and boulders	10 2 0	15.	Inferior coal and shale	1 0 3
4.	Dark-blue shale	12 0 0	16.	Warrant earth	1 0 0
5.	Grey rock and ironstone	0 2 8	17.	Strong blue shale	4 1 10
6.	Strong dark-blue shale	4 0 6	18.	Coal	0 1 11
7.	Grey rock	0 2 0		Soft warrant earth	0 1 6
8.	Very strong light-blue shale (with fossil ferns)	4 1 0	19.	Dogtooth shale and bands of rock	2 2 0
9.	Grey freestone rock, very open, with water	3 0 4	20.	Dark-brown shale	3 2 10
10.	Light-blue shale	4 1 0	21.	Strong grey rock	0 2 6
11.	Coal, inferior	0 2 3	22.	Strong grey shale and bands of rock	1 2 0
	Coal and soft shale	0 1 11	23.	Burr-stone	1 1 3
12.	Warrant earth, very soft	1 1 3	24.	Strong blue shale	3 1 6
	Carry forward	53 0 11		Carry forward	85 0 11

No. on Sect.	Description of Strata.	Thickness. yds.	ft.	in.
	Brought forward	85	0	11
25.	Soft blue shale	0	2	8
26.	Coal, good	0	2	6
27.	Strong warrant earth	1	1	0
28.	Rock burr-stone	4	0	4
29.	Blue shale, strong	3	0	0
30.	Blue shale, soft	1	0	8
31.	Coal, inferior	0	2	6
32.	Warrant earth, strong	1	0	0
33.	Grey shale, very strong	6	0	6
34.	Brown shale, soft	3	0	0
35.	Coal, inferior	0	2	3
36.	Strong grey shale and bands of rock	7	1	8
37.	Soft blue shale	1	0	3
	Black bass	0	1	2
38.	Soft brown shale	2	1	6
39.	Coal, inferior	0	1	6
	Warrant earth	1	0	0
40.	Strong grey shale	11	0	0
41.	Soft dark shale (with vegetable fossils)	0	2	7
42.	Coal, good	1	0	9
43.	Soft warrant earth, mixed with black shaley beds	10	2	0
44.	Black shale	1	0	0
45.	Strong blue shale and rock bands	5	2	8
46.	Strong linn and wool	4	1	0
47.	Soft blue shale	3	2	10
48.	Black bass	1	1	0
49.	Coal, inferior	0	1	5
	Warrant earth	0	0	6
	Coal, fair quality	1	1	8
50.	Warrant earth	1	2	0
51.	Dark-brown shale	1	2	9
52.	Coal	0	0	2
	Warrant earth	0	0	6
	Strong grey shale	2	2	6
53.	Burr-stone	0	1	2
	Strong dark shale	4	0	8
54.	Hoo cannel	0	1	0
	Strong linn and wool	2	0	0
55.	Strong blue shale	6	0	0
56.	Dark shale	0	2	9
	Black bass	0	1	8
57.	Coal, inferior	0	2	9
	Warrant earth	0	0	6
	Coal, inferior	0	1	8
58.	Warrant earth	5	1	10
59.	Blue shale	4	0	5
60.	Dark shale, Jan. 16th, stopped raising headgear, &c.	0	2	4
	Warrant earth, with seams of coal, Feb. 8th, commenced with large engines	2	0	4
	Carry forward	199	0	10

No. on Sect.	Description of Strata.	Thickness. yds.	ft.	in.
	Brought forward	199	0	10
61.	Black bass and warrant earth	3	1	0
62.	Light-blue shale	2	0	6
63.	Bass and warrant	4	2	0
64.	Strong grey shale	2	2	6
65.	Flaggy rock	8	0	0
66.	Strong grey rock	6	0	6
67.	Flaggy rock	2	0	6
68.	Strong grey rock, no joints	13	0	6
69.	Strong grey shale	4	1	0
70.	Strong linn and wool	2	1	0
71.	Strong blue shale	13	1	4
72.	Soft blue shale	1	0	0
73.	Bass and coal	1	2	7
74.	Warrant earth, soft	2	0	9
75.	Coal and bass, 9 in., warrant earth, 9 in.	0	1	6
76.	Coal, inferior	0	1	9
77.	Warrant earth, soft	0	2	6
	Dark dunn shale	0	1	0
78.	Coal, fair quality	1	2	0
79.	Warrant earth	1	0	0
80.	Grey shale	1	2	0
81.	Black bass	1	1	0
82.	Grey shale	5	0	0
83.	Coal, fair quality	0	2	5
84.	Warrant earth	1	0	7
85.	Strong grey shale	4	0	0
86.	Strong grey rock	3	0	0
87.	Flaggy rock, very strong	4	0	0
88.	Linn and wool	0	2	9
	Dark bass	0	0	3
89.	Coal, good	1	1	4
90.	Warrant earth, strong	1	2	6
91.	White rock, very strong	2	2	0
92.	Grey shale	0	1	0
	Coal, inferior	0	1	0
93.	Warrant earth, soft	1	2	6
94.	Linn and wool	3	0	6
95.	Coal and bass	0	0	3
	Warrant earth	0	1	6
96.	Linn and wool	3	1	6
97.	Strong grey shale	12	0	0
98.	Coal and bass	0	0	3
	Warrant earth	1	1	0
99.	Blue shale (with fossil ferns)	4	1	0
100.	Coal and bass	0	2	0
101.	Soft warrant earth	1	2	0
102.	Dark-brown shale (with fossil ferns)	8	2	0
103.	Grey rock	1	0	0
104.	Blue shale	4	1	0
105.	Brown shale	1	0	6
	Coal	0	0	10
	Warrant earth	0	0	4
106.	White rock	1	1	0
107.	Linn and wool	2	2	0
	Carry forward	349	0	9

No. on Sect.	Description of Strata.	Thickness. yds.	ft.	in.
	Brought forward	349	0	9
108.	Burr-stone	0	0	10
	Flaggy rock	1	1	6
109.	Linn and wool	0	2	4
	Dark dunn shale	0	2	4
110.	Strong grey rock	0	2	4
111.	Linn and wool	2	2	0
112.	Light-blue shale and ironstone bands	3	0	0
113.	Dark shale (with freshwater ferns)	4	0	0
114.	Blue shale	2	0	0
115.	Dark shale	1	1	0
116.	Warrant earth	2	2	5
117.	Blue shale (with ironstone bands)	7	0	0
118.	Coal	0	0	4
	Warrant earth	1	2	0
119.	White rock	0	2	0
	Blue shale	2	0	5
120.	Bass, with seams of coal	0	1	4
	Blue shale	1	1	4
121.	Grey rock	0	0	9
	Dark shale	1	2	7
122.	Coal and bass	0	2	0
	Warrant earth	2	1	0
123.	Coal and bass	0	0	8
	Warrant earth	2	1	8
124.	Blue shale	3	1	6
125.	Dark shale	4	0	5
126.	Blue shale	12	0	0
127.	Rock, with layers of shale	7	0	0
128.	Dunn shale	1	1	0
129.	Rock, with thin layers of shale	5	1	0
130.	Strong rock, with vegetable matter mixed	6	2	0
131.	Strong white rock	9	0	6
132.	Blue shale	3	1	0
133.	Black bass	1	1	0
134.	Coal 5 in., shale 2 in., coal 1 yard 0 ft. 6 in.	1	1	1
135.	Warrant earth	0	1	0
	Bass and coal	0	1	6
136.	Warrant earth and bass and coal mixed	4	2	0
137.	Linn and wool	1	1	0
138.	Brown shale	4	1	0
139.	Blue shale	1	0	0
140.	Strong dunn and wool	4	1	3
141.	Blue shale, with layers of dark shale	2	1	3
142.	Black bass and ironstone bands	0	2	6
143.	Coal, good	1	0	7
144.	Warrant earth	0	2	4
	Coal	0	1	9
	Carry forward	468	0	3

No. on Sect.	Description of Strata.	Thickness. yds.	ft.	in.
	Brought forward	468	0	3
145.	Warrant earth	3	1	10
	Coal and bass	0	1	0
146.	Strong blue shale, with fossil ferns	7	0	0
	Dark shale	0	2	0
147.	Strong grey shale	10	2	8
148.	Blue shale	1	1	6
	Bass	0	1	0
149.	Coal	0	0	6
	Bass	0	0	5
	Coal	0	0	3
	Warrant earth	0	0	1
	Coal and warrant earth mixed	0	0	6
	Coal and bass	0	1	7
	Coal, inferior	0	1	6
	Coal and bass	0	1	2
	Coal, inferior	0	2	9
150.	Warrant earth	0	0	8
	Blue shale	7	2	0
151.	Coal and bass	0	0	6
	Warrant earth, mixed with coal	4	0	0
152.	Strong grey shale	4	2	0
153.	Warrant earth	1	0	0
154.	Strong grey shale, with beds of linn and wool	13	1	7
	Strong blue shale, with layers of rock	3	0	0
155.	Strong freestone rock	16	2	0
156.	Black bass	1	0	0
157.	Blue shale	0	2	8
	Coal	0	1	0
158.	Warrant earth	1	2	6
159.	Strong blue shale	6	2	4
160.	Dark shale	0	1	0
	Strong grey shale, with layers of linn	13	0	0
161.	Dark-brown shale, with layers of bass	2	0	0
162.	Dark warrant earth and shale	2	0	4
	Coal	0	0	7
163.	Dark warrant earth	1	0	0
164.	Dark shale	2	2	2
165.	Dark layers of shale	0	2	10
166.	Coal, fair quality	0	1	2
	Warrant earth	0	1	0
167.	Coal shale	1	0	2
	Warrant earth	0	0	0
168.	White rock	1	0	6
169.	Flaggy rock	1	1	4
170.	Light-brown rock	1	0	4
171.	Strong grey shale	1	0	4
172.	Blue shale	1	0	6
173.	Dark bass	1	1	9
	Carry forward	588	2	3

No. on Sect.	Description of Strata.	Thickness. yds.	ft.	in.
	Brought forward	588	2	3
174.	Hoo cannel	0	2	7
	Ironstone bass	0	0	3
	Hoo cannel	0	0	5
175.	Cannel	1	0	0
176.	Dark stony bass	0	1	2
	Shale, with seams of coal	0	2	2
	Bass	0	0	3
177.	King coal tops	0	2	0
178.	Coal and shale	1	0	11
179.	King coal bottoms	0	1	6
180.	Warrant earth	1	0	0
181.	Coal	0	0	6
	Soft warrant earth	1	0	0
182.	Light shales	1	1	4
183.	Strong blue shale	5	2	0
184.	White rock	1	1	0
185.	Strong blue metal	4	2	4
186.	Soft metal	1	1	2
187.	Linn and wool	1	0	4
188.	Rock	10	2	4
	Metal with brown iron bands	5	2	11
189.	Coal	0	0	11
	Earth	0	0	3
	Coal	0	0	11
	Earth	0	0	10
	Coal	0	1	3
	Coal and bass	0	0	8
	Metal	0	0	7
	Coal and bass	0	0	6
	Coal	0	1	10
	Metal	0	0	6
	Coal	0	1	9
190.	Dogtooth shale or warrant	0	4	6
191.	Strong linn and wool	0	4	3
192.	Strong metal, with iron bands	3	2	6
193.	Bass	0	1	6
	Coal	0	0	2
	Warrant earth	0	1	0
194.	Linn and wool	6	2	0
195.	Strong metal, with iron bands	6	1	6
196.	Black bass	0	0	6
	Inferior cannel	0	0	9
	Blue metal	0	1	3
197.	Dark-grey rock	1	0	6
198.	Linn and wool	2	2	5
199.	Strong grey metal and iron bands	1	2	0
200.	Linn and wool	3	1	3
201.	Coal	0	0	9
	Black bass	0	0	10
	Carry forward	663	2	1

No. on Sect.	Description of Strata.	Thickness. yds.	ft.	in.
	Brought forward	663	2	1
202.	Dark dunn metal and iron bands	6	1	9
203.	Coal and bass	0	0	6
	Soft metal	0	0	6
204.	Coal	0	2	8
205.	Warrant earth	0	0	8
	Strong grey rock	2	0	10
206.	Flaggy rock	3	2	3
207.	Linn and wool	1	0	0
208.	Blue metal	2	0	0
	Coal	0	0	1
209.	Linn and wool	5	0	0
210.	Strong blue metal and iron bands	12	0	0
211.	Dark dunn shale	4	0	0
212.	Coal	0	0	4
	Warrant earth	2	0	0
213.	Strong linn and wool	11	0	0
214.	Dunn bass	0	2	0
	Coal	0	1	6
215.	Warrant earth	2	0	0
216.	Dark rock	2	0	0
217.	Linn and wool	6	2	6
218.	Coal and bass	0	0	9
	Warrant earth	2	0	0
	Bass and coal	0	0	6
219.	Dogtooth shale	2	0	0
220.	Strong blue metal	3	1	3
221.	Strong grey rock with burrs	3	1	9
222.	Strong metal	3	1	9
223.	Coal, inferior	0	1	2
224.	Warrant	1	0	0
225.	Rock	1	0	0
226.	Blue metal	9	0	7
227.	Cockle-shell bed	0	2	0
228.	Black bass	1	0	0
229.	Blue metal	2	0	0
230.	Rock	2	0	0
231.	Blue metal	2	0	0
232.	Linn and wool	1	2	5
233.	Grey rock	2	0	0
234.	Linn and wool	10	0	0
235.	Blue metal	8	0	0
236.	Black bass	1	0	0
237.	Blue metal	1	0	0
238.	Grey rock, mixed	15	1	0
239.	Blue metal	4	2	6
	Black bass	0	0	6
240.	Coal	1	0	8
241.	Warrant earth	1	1	0
242.	Rock	5	0	0
243.	Strong shale	2	1	0
	Total	815	0	6

Section of the Boring at Kentish Town.

					Depth.	
			ft.	in.	ft.	in.
Tertiary Strata, 234 ft. 6 in.	London clay (236 ft.)	1. Yellow clay	30	6		
		2. Blue clay, with *Septaria*	205	6		
	Woolwich and Reading series (61 ft. 6 in.)	3. Mottled (red, yellow, and blue) clay	37	6	273	6
		4. White sand, with flint-pebbles	0	6		
		5. Black sands; *passing into*	2	0		
		6. Mottled green and red clay	1	0		
		7. Clayey sands	3	0		
		8. Dark grey sands with seams of clay	9	6		
		9. Quicksands, ash-coloured	6	6		
		10. Flint pebbles	1	6		
	Thanet sands (27 ft.)	11. Ash-coloured sands	10	0	307	6
		12. Argillaceous sands	4	0		
		13. Dark-grey clayey sands	11	0		
		14. Bed of angular green-coated flints	2	0	324	6
Chalk, 586 ft.	Middle chalk with flints (244 ft. 6 in.)	15. Chalk with flints	119	6		
		16. Hard chalk without flints	8	0		
		17. Chalk, less hard, with few flints	31	6	483	6
		18. Nodular chalk, with three beds of tabular flints	13	6		
		19. Chalk, with seams of tabular flint and a few nodular flints	32	6	529	6
		20. Chalk, with a few flints and some patches of sand	9	6		
		21. Very light-grey chalk, with a few flints	30	0	569	0
	Lower chalk without flints (294 ft.)	22. Light-grey chalk, with a few thin beds of chalk-marl subordinate	133	0	702	0
		23. Grey chalk-marl, with compact and marly beds and occasional pyrites	161	0	863	0
	Chalk-marl (47 ft. 6 in.)	24. Grey marl	20	0		
		25. Harder grey marl, rather sandy, and with occasional iron-pyrites	27	0		
		26. Hard rocky marl	0	6	910	6
	Upper Greensand (72 ft. 6 in.)	27. Bluish-grey marl, rather sandy; the lower part more argillaceous	58	9		
		28. Dark-green sand, mixed with grey clay	13	9	983	0
	Gault (130 ft. 6 in.)	29. Bluish-grey micaceous clay, slightly sandy	39	0		
		30. Ditto, with two seams of argillaceous greensand	6	7		
		31. Micaceous blue clay	84	11	1113	6

Second Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals for Photographing. The Committee consists of Henry Woodward, *F.G.S.*, Prof. Duncan, *F.R.S.*, Prof. Harkness, *F.R.S.*, *and* James Thomson, *F.G.S.*

In presenting to the Association the second Report on the slicing of corals from the Mountain Limestone, for the purpose of showing their structural characteristics by means of photography, we have to state that considerable progress has been made during the year, but much still remains to be done

before we can prepare a final Report. The Plates exhibited to the Section and described below show some valuable results.

Milne-Edwards and Jules Haime, in their paper on the Corals from the Mountain Limestone, published in the Transactions of the Palæontographical Society for 1852, state that this period is one of the richest in true Polyps, and that 76 species up to that date have been found; of these, they record 43 as found in British strata. In the progress of our investigations we so greatly add to this number that, from Scottish strata alone, we have obtained 64 species belonging to the following families:—

	Known.	Doubtful.
Milleporidæ	8	0
Favositidæ	4	0
Chætididæ	5	3
Halysitina	3	1
Seriatoporidæ	1	0
Auloporidæ	1	1
Cyathaxenidæ	1	5
Cyathophyllidæ	41	82
	*64	92

Although some of these forms have been determined from somewhat imperfect data, we have no doubt that the continued investigation of these remains will yet greatly increase their number, and cause considerable alterations in their classification; we consequently feel the necessity of being more severe in our labours, not only with the view of adding to the knowledge of species, but of getting rid of the numerous synonyms which encumber the study of this interesting group of animal remains.

Plate I. contains the genera *Amplexus*, *Zephrentis*, *Cyathophyllum*, and *Campophyllum*. Fig. 1 represents *Amplexus coralloides* (Sow.); fig. 7, *A. Henslowii* (Edwards & Haime). This genus is characterized by broad tabula and sparsely developed endotheca. These species are much restricted in their vertical range: we are not aware of their being found in any other position than in the lower members of the series. *A. coralloides* has been found at Beith, Ayrshire, and at Brockley, near Lesmahagow, Lanarkshire; *A. Henslowii* at Brockley, Lesmahagow. Figs. 3, 6, & 9 represent the genus *Zephrentis*; fig. 3, *Z. cylindrica* (Scoular). This form is restricted to the lower beds. Fig. 6, *Z. Griffithi*. This species is found in all the members of the Mountain Limestone. It has a vertical range of 3000 feet. Fig. 11, *Z. Gueranyeri*; it is restricted to the lower beds, and is found at Auchenskeigh, Ayrshire. Fig. 2 is closely allied to fig. 3, and is probably a young form. Figs. 5 & 9 differ in the arrangement of the tabulæ. Figs. 8 & 10 represent the genus *Cyathophyllum*; fig. 8, *C. Murchisonii*. This species is very rare in Scotland, and found only in the lower beds at Bathgate, Linlithgowshire. Figs. 10 & 10 A, *C. paricida*. This species is also restricted to the lower beds. It is found at Beith, Ayrshire, and is not rare. Fig. 4, *Campophyllum Murchisonii*. This and the preceding forms are developed by calicular gemmation. In the longitudinal section of fig. 4, we have a young coral attached to the calice of the parent. In comparing the genus

* The 64 species referred to have been named from the works of Milne-Edwards and Haime and M'Coy. Those referred to as doubtful seem to us to have structural characteristics sufficient to warrant specific distinction; but as our investigations are not sufficiently advanced to warrant their determination, we reserve their classification for a future contribution.

Campophyllum with *Cyathophyllum* and *Zaphrentis cylindrica*, we cannot see any good grounds for these forms being placed in separate genera. The tabula and endotheca are very similar in all the three forms.

Plate II. presents important structural confirmations. Fig. 1, *Cyathophyllum Wrighti*. Figs. 3, 10, & 13 are closely allied to *Cyathophyllum*, and probably may form a subgenus. They are all restricted to the lower beds, and are found at Brockley, Lesmahagow, and at Howret, Ayrshire. Figs. 2, 4, 6, 7, 8, 9, 11, 12, 14, 15, & 16 have close affinities to the genus *Clisiophyllum* (Dana), but there is a distinctly marked difference in the structural characteristics from those of any known species. All are restricted to the lower members of the period, and are found at Brockley, Lesmahagow.

Plate III. contains seven varieties of the genus *Clisiophyllum* (Dana). This genus is characterized by the conical boss in the centre of the calice, and by the central line which passes down from the apex of the cone to the inferior extremity. Figs. 1, 3, & 4 have close affinities to fig. 6, which represents *C. bipartitum* (M'Coy), while there is a distinctly marked difference in structural characteristics. Figs. 2, 5, & 7 differ very materially from the others, and cannot be referred to any named species. They are all found in the lower members of the period at Beith, Ayrshire.

Plate IV. contains five varieties. Fig. 5, *Clisiophyllum coniseptum* (Keyserling). This is the only named species represented on this Plate. Figs. 1, 2, 3, & 4 differ very materially from any existing genus; they are not only restricted to the lower members of the period, but also to a very limited area of the period. They have only been found at Treahorn, near Beith, Ayrshire.

Plate V. fig. 4 has close affinities to *Clisiophyllum coniseptum*. Fig. 1 has a clear generic distinction from all the others found that have passed through our hands. This coral we have found 10 inches in height, and frequently 2 inches in diameter. It is the largest form of this class we have yet seen. Figs. 4 & 5 are closely allied to figs. 1 & 4 of Plate IV. These, like the former, are all restricted both in vertical range and in area. They have only been found at Treahorn, near Beith, Ayrshire.

Plate VI. figs. 1, 2, & 5 are three varieties of the genus *Clisiophyllum* (Dana), but they cannot be referred to any existing species with which we met. They are restricted both in vertical range and area. They are only found at the base of the rocks of this period, and are met with at Thirdpart, near Beith, Ayrshire. Figs. 3 & 4 show a distinctly marked difference in the essential characteristics from any known genus. They are found in the lower beds at Brockley, near Lesmahagow, and at Treahorn, Beith, Ayrshire.

Plate VII. contains varieties of *Cyclophyllum* (Duncan & Thomson). Fig. 6 represents a section of the original *fungitus* of the Rev. David Ure; it is figured in his 'History of Rutherglen and East Kilbride,' in 1793. The original specimen is in the collection of the Royal Society of Edinburgh. By permission of the Council, we sliced that specimen with a view to ascertain to what genus it could be referred. The history of this specimen is perhaps one of the best illustrations on record showing the necessity of carefully working out the details of fossil corals before they receive either generic or specific names. It was named *fungitus* by Ure in 1793, *Turbinolia fungitus* by Fleming in 1828, *Cyathophyllum fungitus* by Geinitz in 1845, *Clisiophyllum prolapsum* by M'Coy in 1849, *Aulophyllum fungitus* by the same authors in 1851 who named it *Aulophyllum prolapsum* in 1845;

viz. Milne-Edwards and Haime. This great diversity of nomenclature we can only attribute to the fact that non-essential and external characteristics have been too implicitly trusted in drawing generic distinctions; when we examine their internal structures, genera named exhibit essential differences of conformation. This genus is found all over Scotland, but is restricted to the base of the Mountain Limestone.

Plate VIII. figs. 4, 5, & 14 represent varieties of *Cyclophyllum fungitus*; fig. 13, *C. Bowerbankii.* Figs. 1, 2, 3, 6, 7, 8, 11, & 12 represent species which have a distinctly marked difference from the two species named. Fig. 9 is *Aulophyllum Edwardsi* (Duncan & Thomson). This is a section of the typical specimen, the only one, so far as we are aware, that has been discovered in British strata. These forms are all restricted to the lower members of the period; they are found at Bathgate, Brockley, and Beith, Ayrshire.

Plate IX. contains three varieties of the genus *Lonsdalia.* Fig. 4 represents *L. floriformis.* This species is restricted to the lower members of the period, as found at Bathgate, Linlithgowshire. Figs. 1 & 2 are *L. floriformis,* var. *major.* This species is restricted to the position of the Main Limestone, about 33 feet from the base of the Mountain-Limestone series, and found at Braghead, Lesmahagow, and Braidwood, Carluke, Lanarkshire. Fig. 4 represents *L. duplicata* (Fleming). This is a section of the only specimen we have seen in Scotland. It is restricted to the lower member of the period, and found at Glenmuirshaw, near Muirkirk, Ayrshire.

Second Report of the Committee, consisting of C. W. MERRIFIELD, *F.R.S.,* G. P. BIDDER, *C.E., F.R.G.S.,* Capt. DOUGLAS GALTON, *F.R.S.,* F. GALTON, *F.R.S.,* Prof. RANKINE, *F.R.S., and* W. FROUDE, *appointed to report on the state of existing knowledge on the Stability, Propulsion, and Sea-going Qualities of Ships, and as to the application which it may be desirable to make to Her Majesty's Government on these subjects. Prepared for the Committee by* C. W. MERRIFIELD, *F.R.S.*

WE have to report that we have availed ourselves of your permission to apply to the Admiralty to carry out the experiments recommended in our first Report, presented to the British Association at Exeter last year, and that the Admiralty have declined to carry out these experiments, but they have sanctioned certain experiments upon models to be conducted by Mr. Froude, one of our number.

The following is a copy of the correspondence on the subject.

Institution of Naval Architects,
9 Adelphi Terrace, London, W.C.
28th September, 1869.

To the Secretary of the Admiralty.

SIR,—At a Meeting of the British Association for the Advancement of Science, held at Norwich in 1868, the attention of the Association was drawn to the deficiency of existing knowledge on the stability, propulsion,

and sea-going qualities of ships, and to the need of further experiments on those subjects as a basis for the extension of theoretical investigation.

A Committee, consisting of Mr. Bidder, Capt. Galton, Mr. F. Galton, Prof. Rankine, Mr. Froude, and myself, was appointed for the purpose of reporting on the state of existing knowledge on these subjects. At the recent Meeting at Exeter this Committee presented a first Report, in which they recommended certain experiments involving trials on too large a scale to be undertaken by private individuals; and the Association thereupon reappointed the Committee, and instructed them to apply to the Admiralty to carry out the experiments suggested.

I enclose six copies of the Report, and also an extract showing the experiments actually recommended.

With regard to the general question, it is submitted that there is a great want of exact experiments on vessels of which every particular is duly known and recorded. The experiments will undoubtedly require that a certain outlay should be incurred, and provided for in the estimates; but it is believed that even a considerable sum invested in this way would probably economize much larger amounts, which would otherwise have to be spent in the tentative design of ships and propellers.

The Committee have indicated in their Report the class of experiments which they consider to be immediately required. They have purposely abstained from giving detailed proposals, both because they desire to avail themselves of the immense experience of the naval advisers of the Admiralty and of the unrivalled technical knowledge of the constructor's department, and because the details must after all be settled with reference to the vessels selected for, and the staff entrusted with, the experiments decided upon.

If My Lords should be pleased to give a general assent to the proposal, it appears to the Committee that the simplest plan would be for their Lordships to appoint some of their officers to confer with the Committee of the Association, both as to the detail of the experiments and the best means of carrying them out, and with regard to the provision which will be needed for them in the estimates.

The Committee wish it to be understood that they do not by any means discourage experiments made by means of models, which can evidently be had in greater number and in larger variety at much less expense than on full scale; but they have (with the exception of Mr. Froude, whose reasons for dissent are appended to the Report), on the whole, come to the conclusion that the experiments which they have recommended *upon full-sized vessels* are those which at the present moment are most urgently needed for the advancement of the theory of the design of ships and the possibility of predicating their sea-going qualities.

I have, &c.,
C. W. Merrifield.

Admiralty, S.W.
9th February, 1870.

Sir,—With reference to your letter of the 28th September, 1869, I am commanded by My Lords Commissioners of the Admiralty to inform you that, after full consideration, they are unable to give a general assent to the proposals of your Committee to conduct experiments upon Her Majesty's ships in the fiords of Norway, or on the inland waters of the west coast of Scotland; but My Lords have been pleased to sanction certain experiments upon models, to be conducted by Mr. Froude, a member of the Committee,

and will cause the results of those experiments to be communicated, when complete, to the Institution of Naval Architects, the British Association, and such other Professional bodies as to My Lords may seem desirable.

I am, Sir, your obedient Servant,
(Signed) VERNON LUSHINGTON.

C. W. Merrifield, Esq., F.R.S.,
Secretary to the Committee on Stability &c. of British Association.

We are of opinion that it is advisable to await the result of Mr. Froude's experiments before taking any further action in the matter.

FRANCIS GALTON.
G. P. BIDDER.
DOUGLAS GALTON.
W. J. MACQUORN RANKINE.
WM. FROUDE.
CHARLES W. MERRIFIELD.

London, May 1870.

APPENDIX.

Communication received from the Institution of Engineers in Scotland, with which is incorporated the Scottish Shipbuilders' Association.

Report of the Committee on a Communication received from the British Association respecting the Qualities of Ships.

Your Committee having considered the printed Report of a Committee of the British Association which has been submitted to them by the Council and other information on the same subject, beg leave to report as follows:—

1. Your Committee approve of the said Report generally, and especially of the parts headed "Proposed Experiments," pages 29 to 31, and "Recommendation of Experiments on Rolling," pages 59 to 63; for they consider that such experiments as those therein proposed are required for the practical advancement of the arts of Naval Architecture and Marine Engineering, as well as for scientific purposes.

2. Your Committee agree with the Committee of the British Association that the experiments required are beyond the means either of individuals or of firms, or of Scientific Societies; and that it is therefore desirable that they should be undertaken by the Government.

3. Your Committee therefore recommend that the Council of the Institution of Engineers in Scotland should appoint a deputation, for the purpose of cooperating with the deputation of the Council of the British Association in the application to the Admiralty proposed in the last paragraph of page 31, and in the last paragraph but one of page 62, of the printed Report before mentioned, which paragraphs are as follows:—

Page 31.—"We therefore recommend that the Council of the British Association should authorize a deputation to apply to the Admiralty to provide for such a set of experiments in the course of the Summer of 1870; also, that the Council should appoint a Committee, consisting of three members of the Association, to confer with officers of the Admiralty respecting the detail of the experiments, and that the Admiralty should be requested to give an opportunity to the members of that Committee of taking a share in the observations, in order that they may be enabled to make an independent Report upon results."

Page 62.—"We therefore recommend that the deputation previously mentioned with reference to the experiments on Resistance, be also instructed

to urge upon the Admiralty the importance, both practical and theoretical, of instituting such a set of experiments, of providing suitable instruments for recording exact observations, and of publishing the results. We also recommend the appointment by the Council of the Association of a Committee of *three* members to confer with the officers of the Admiralty as to the drawing up of detailed instructions for conducting these experiments; and that the Lords of the Admiralty, in the event of their assenting to the proposals, be requested to nominate a committee to confer with the Committee named by the Association."

4. As regards the proposal in the printed Report, that the Council of the British Association should appoint a committee of three members of the Association to confer with the officers of the Admiralty, your Committee recommend that the Council of the Institution of Engineers in Scotland should also appoint a Committee of three members of this Institution for the same purpose; and that, in appointing that Committee, in order to avoid making the combined committees inconveniently numerous, they should endeavour, by communication with the Councils of the British Association and of the other Scientific Societies concurring in the application to Government, to fix upon members of committee who may represent two or more societies jointly.

5. Your Committee recommend to the consideration of those who may arrange the experiments a method of experimenting on the resistance of the water to the motion of ships lately practised by the French Government, viz. to set a ship in motion at a considerable speed, and then allow her to be gradually retarded and brought to rest by the resistance of the water, making observations of the rates at which the retardation goes on, and deducing the resistance from the results of those observations.

Your Committee recommend this method not as a substitute for, but as an addition to, the methods mentioned in the printed Report; for they consider that important conclusions may be deduced from a comparison of the values of the resistance of a ship as ascertained by towing and by retardation respectively.

Extract of Minutes relating to Communication from British Association respecting the Qualities of Ships.

Council Meeting of 15th October, 1869.

"A letter from C. W. Merrifield, in reference to a Report of the British Association on the Stability, Propulsion, and Sea-going qualities of Ships, was read, and Report laid before the Meeting.

"The following Committee was appointed to consider this Report, and report to a future Meeting:—Professor Rankine, Messrs. M. R. Costelloe, R. Duncan, John Ferguson, J. G. Lawrie, and David Rowan."

Council Meeting of 18th January, 1870.

"The Report of the Committee appointed to consider communication from the British Association respecting the Qualities of Ships was read and agreed to."

General Meeting of 18th January, 1870. See Special General Meeting.

Special General Meeting of 25th January, 1870.

"The Secretary read the Report of the Council on communication from British Association in reference to experiments on the Stability, Propulsion, and Sea-going Qualities of Ships. The Report was unanimously adopted."

Council Meeting of 4th February, 1870.

"Communication from British Association.—It was agreed that the following gentlemen be appointed a Committee to act with the Committee of the British Association with a view to the carrying out the recommendations contained in the Report of the Committee on a communication from the British Association respecting the qualities of Ships:—Professor Rankine, Jas. R. Napier, and J. G. Lawrie."

(Extracted.) J. R. Smith, *Secretary.*
W. H. Millar.

Report of the Committee on Earthquakes in Scotland. The Committee consists of Sir W. Thomson, *M.A., LL.D., F.R.S.,* D. Milne-Home, *F.R.S.E.,* P. Macfarlane, *and* J. Bryce, *M.A., LL.D., F.G.S.* (Reporter).

The instruments belonging to the Association, set up at Comrie, are in a satisfactory condition, and the records are duly kept. It has, however, been of late forced upon the attention of the Committee that most probably the Seismometer is not sufficiently delicate to indicate the very slight shocks which are now of frequent occurrence, while the concave disk, on which the pencil-point traces the direction of the shock, is inconveniently high for frequent observation. Under these circumstances some simpler contrivance, and one which shall give less trouble to the observer, is much to be desired. The Committee is now considering how this can be best accomplished, with special reference to the registration of slight shocks by some method of magnifying the effect. Care will be taken that the instrument be thoroughly tested before being set up at Comrie, and that the cost be as small as possible. In the autumn of last year there were several slight shocks, and, apparently in connexion with them (though it would be rash to speak positively on this point), a remarkable movement of the waters of Loch Earn, though the shocks were not felt at that distance from Comrie. The matter being reported to me, I went into the district soon after, and collected the most satisfactory evidence of the movement in question. It occurred on several occasions in the months of August and September last; but the most remarkable and most completely attested case was that of the 15th day of September, between the hours of 10 A.M. and noon. The day was calm and misty, with a slight air up the lake from the east, and the water consequently quite unruffled. At the east end chiefly the movement was observed. The water rose slowly, in successive low, broad undulations, to the height of from 2 to 6 feet, along the shelving beach, and as slowly subsided, the undulations continuing through the two hours of the forenoon above mentioned. There was nothing sudden or disturbed in the movement; in so far it was unlike the effect of earth-waves passing into water; it resembled more the movements which are at rare intervals noted in the lakes of Switzerland, and may be the effect of subterranean movements at great distances. Instruction had been given for the careful observation of any such occurrences in future.—On the 29th of April last, about 11 P.M., a pretty smart shock of earthquake was felt over the district, to the extent of 10 miles along the valley of the Earn, and about half that distance in a transverse direction. There were

two shocks, with an interval of about half a minute. The direction whence the undulation seemed to all the observers to proceed in different parts agreed pretty closely with that indicated by the Seismometer. There was nothing unusual, or in any way remarkable, in the indications of the instruments by which the atmospheric phenomena are recorded. The movements, indeed, are more probably connected with the geological relations of the district, and may have no dependence on its meteorology. It is, however, premature to enter on this question in the present state of the inquiry. The Committee is most desirous to be enabled to put up two or three Seismometers in other adjacent localities, if any instrument of manageable size can be constructed, and thoroughly capable and trustworthy observers secured.

Report of the Committee on the "Treatment and Utilization of Sewage," reappointed at Exeter, 1869, *and consisting of* Richard B. Grantham, *M. Inst. C.E., F.G.S., Chairman,* M. C. Cooke, *M.A.,* Prof. Corfield, *M.A., M.B.,* J. Bailey Denton, *M. Inst. C.E., F.G.S.,* John Thornhill Harrison, *M. Inst. C.E.,* William Hope, *V.C.,* Prof. Marshall, *F.R.C.S., F.R.S.,* Benjamin H. Paul, *Ph.D., F.C.S.,* Prof. Wanklyn, Prof. Williamson, *Ph.D., F.R.S., and* Sir John Lubbock, *Bart., M.P., F.R.S., Treasurer.*

[Plates I., II., III.]

Before describing its operations during the past year, your Committee desires to recall the attention of the Association to the circumstances which led to its reappointment at Exeter last year.

Your Committee was first constituted at Norwich in 1868, with a grant of £10 "to report on the treatment and utilization of Sewage." The results of its inquiries were detailed in the Report made to the Exeter Meeting in 1869, and the Committee was reappointed with a grant of £50, being then constituted as follows:—

Mr. Grantham, Mr. Denton, Mr. Harrison, Mr. Hope, Dr. Paul, and Professor Wanklyn.

The Committee as soon as possible made arrangements to proceed with the inquiry entrusted to it; and one of the first steps taken upon resuming its operations was, in virtue of the power vested in all Committees, to add to its number several gentlemen whose assistance was considered desirable, namely, Mr. Cooke, Professors Corfield, Marshall, and Williamson, and Sir John Lubbock as Treasurer with respect to the Fund raised by the Committee as hereafter described.

The Committee proceeded to collect existing information upon the subject of sewage &c. with a view to summarizing it.

It soon became evident to the Committee that the grant of £50 from the British Association would be wholly insufficient for carrying on the investigations in a broad and comprehensive manner. A circular was thereupon prepared and addressed to the authorities of the towns principally interested in the solution of the difficulties in connexion with the disposal of sewage, who it was thought would, if requested, subscribe towards a fund for carrying on the investigations. The draft of this circular was submitted

to the Council of the Association. The circular was then issued, at various times, to upwards of 700 towns in the United Kingdom. The result of these applications has been that the authorities of about 150 towns and districts, in addition to other public bodies and some private individuals, have subscribed the sum of £1530. There was a general expression of satisfaction from the towns at the appointment of the Committee, who received numerous offers of assistance in the prosecution of its inquiries.

The various applications to the towns occupied some time, during which the Committee was unable to take active steps in the prosecution of the inquiry, the scope and character of which would necessarily be governed by the amount of support rendered by the towns; and it was not until the end of February that the Committee found itself in a position to proceed with the full inquiry proposed by its circular. The Committee then considered that the funds received justified the commencement of systematic work, and a circular was at once addressed to the authorities of all the towns requesting them to state the nature of their difficulties with respect to the sewage question, and the points upon which they would specially desire information. In reply to this many communications were received detailing the particular circumstances of the various towns, and the difficulties complained of. The information required may be briefly summarized as follows:—

The towns complaining of difficulties may be classed under two heads—those having efficient arrangements for the removal of their sewage, and those where, for want of systematic sewerage, the refuse is a source of nuisance and injury to health. The latter class of towns seems to require information upon all points, and some of the municipal authorities, against whom injunctions had been obtained or threatened, even wished for advice in their particular cases. Where irrigation was considered from local circumstances impracticable, inquiry was particularly made as to whether the Committee could safely recommend any simple and efficient method of deodorization. Several towns which had adopted methods of filtration complained of their failure. Some towns had no present trouble to complain of, but wished to know how far the systems adopted by them would meet the requirements of a more stringent legislation on the question. Only one town (Carlisle) where irrigation is being practised had no difficulty, present or prospective, and required no information.

The Committee being desirous of restricting its labours to the proper subject of the inquiry entrusted to it, viz. the "treatment and utilization of sewage," and assuming as proved the deleterious effects upon the health of towns of substances which escape from stagnant sewage into the surrounding soil, water, and atmosphere, resolved "that it was unnecessary to enter upon any special medical or other hygienic investigation for the purpose of establishing that general conclusion, but that it would direct its special attention to the extent to which the soil, water, and atmosphere are polluted by the several systems adopted for removing sewage from towns." It decided also to take into consideration the probable sanitary advantages or disadvantages of different methods of treating sewage after removal, and the effects upon the public health of the various methods proposed for its utilization.

The Committee considered it desirable that all persons having processes for the purification or utilization of sewage should be applied to, to submit them for examination, and to furnish details of the principle and working of their respective plans; advertisements were accordingly issued. Descriptions of several methods and some suggestions have been received; these, however, have not yet been examined.

The Committee continued its investigation of last year into the modes of treatment and utilization now practised, and a form was prepared and sent to the principal towns for the purpose of obtaining further information on the subject. The replies received from 200 of these towns have been tabulated. The Table and a statement describing the results of this part of the inquiry will be found further on in this Report.

The Committee decided upon making local investigations in towns typically representing various methods for the disposal of refuse matters, and for this purpose appointed two engineers to make the inquiries. Cambridge and Bury were first selected for examination, as being good examples of water-closet and privy and ashpit towns respectively.

The Committee considered it desirable that the existing information bearing upon the subject of the present inquiry should be collected in the form of a "Digest," which Professor Corfield undertook to prepare; he has done so, and it will be distributed with this Report to the towns which have subscribed to the Committee's fund.

The Committee availing itself of the proximity to London of the town of Romford, a lease of the sewage of which for irrigation upon "Breton's Farm" happened to have been taken by one of its members, appointed a person to reside on the farm to make observations as the cropping progressed, to take gaugings, and to collect samples for analysis, both of the sewage and of the effluent water. He has proceeded with the work, and the observations &c. have been tabulated and a plan has been made of the farm as laid out for sewage irrigation, with the engines, tank, distributing-troughs, carriers, beds, and underdrains, all of which are explained in the special description of this farm, which will be found in an appendix to this Report.

The Committee appointed Dr. Russell, of St. Mary's Hospital, London, to make such analyses as they might require, and those referred to and given in the description of Breton's Farm and other portions of this Report have been furnished by him.

As some apprehensions have arisen to the effect that the distribution of sewage over the land might possibly favour the spread of entozoic diseases in various ways, and might even propagate some that have not yet been known to spread in our country, the Committee has thought it desirable to institute a series of experiments with a view to deciding this point, or at any rate throwing some light upon it. To this end three families of guinea-pigs have been purchased, each family consisting of four members: one member of each family has been examined by Professor Corfield, who reports that no sign of entozoic disease of any description was to be found with the help of a powerful pocket-lens, either in the viscera or muscles of either specimen examined.

The three surviving members of one family are now being fed on sewaged produce only, and those of the other two families on unsewaged produce only: it is proposed to feed the members of one of these last-mentioned families with an occasional meal containing entozoic larvæ or ova, found either upon the sewaged vegetables (it having been stated that some have been so found on the Craigentinny meadows), or, failing that, in the sewage itself.

Thus there will be three families of three members each; of which one family will have been fed upon sewaged produce alone, one on unsewaged produce alone, and one on unsewaged produce known to contain entozoic larvæ or ova.

The animals will then be killed and carefully examined; and it is hoped that some result may be obtained even from this preliminary experiment,

although conducted on so small a scale. The Committee, however, fully intends to prosecute the inquiry further, and to institute experiments of this nature on a larger scale.

It may be added here that some specimens of sewage-grown rye-grass, carrots, turnips, onions, beet, and lettuce, from Breton's farm, were sent to Mr. M. C. Cooke, M.A., for examination, with a view to the possible discovery of entozoic eggs or larvæ. He states that "the rye-grass was mouldy, but only from such moulds as are the result of decay from the damp grass having been kept several days enclosed;" and he summarizes the results of his examination of the vegetables as follows:—"I find nothing whatever to report against any of them. They all seem to me in excellent order and free from parasitic insects, or from fungi of any kind."

The foregoing Report is a brief account of the work done by the Committee since the last Meeting of the Association at Exeter. Further details will be found in the appendices; but in the present immature stage of so important and difficult an inquiry the Committee can only report progress, reserving for a future, and it is hoped early Report, the practical conclusions and suggestions resulting from its labours.

APPENDIX.

A.—*Abstract of Returns from* 200 *Towns.*

Returns have been received from a large number of towns, recording the existing arrangements of water-supply, sewerage, scavenging, and disposal of refuse; and the returns from 200 of these have been tabulated by the Committee with a view to the selection therefrom of typical towns for examination. They are arranged consecutively, from 1 to 200, under the headings "Registration Divisions," "Counties," and "Watersheds." Under the first heading all the Registration Divisions recognized by the Registrar-General in England and Wales are included, with the exception of that of London. Under the second heading all the counties of England appear, except Rutland, Huntingdon, and Westmoreland, while Wales is represented by seven towns. Scotland and Ireland contribute eight and four towns respectively. Out of the 220 watersheds into which England and Wales are divided, 39 appear in the schedule, and these comprise the principal rivers.

The 200 towns and districts enumerated contain a population of 7,159,240.

The whole of the towns in Great Britain and Ireland may be divided into the three classes stated below, and the number of the tabulated towns in each class is duly stated.

	No.	Population.
I. Towns having a complete system of underground sewerage, a general water-supply, and a general adoption of water-closets discharging into the sewers	44	1,154,600
II.* Towns having a system of underground sewerage with water-supply, and only a partial adoption of water-closets	145	5,785,840
III. Towns without any system of underground sewerage	11	218,800
		7,159,240

* In this class there are some towns with as few as six water-closets only.

Considerable difficulty has been experienced in classifying the tabulated towns, owing to the fact that sanitary arrangements have not, except in a few instances, reached the point where complete systems may be said to exist. This will be apparent on an analysis of the following details of returns.

Water.—In the supply of water, the greatest irregularity prevails. There are few towns in which the whole of the inhabitants derive their supply from public sources, these being largely supplemented by water from wells and roofs. The quantity of water, too, supplied for public or general uses and for special trades and purposes, varies very considerably, while the waste is much greater in some towns than in others. In the 200 scheduled towns there are 90 wholly dependent on a public or general supply, 22 on private sources only, and 88 partly on private sources, in addition to a public supply. The returns show that there are in the 200 scheduled towns and districts 7 towns with a public daily supply of water amounting to or exceeding 50 gallons per head, 6 between 40 and 50, 18 between 30 and 40, 46 between 20 and 30, 38 between 10 and 20, and 4 under 10 gallons. The remainder, consisting of 81 towns, have made no return as to the quantities supplied.

Receptacles of Excretal Matter.—With respect to this subject, there is quite as much diversity of treatment and want of precise knowledge as with respect to water-supply. In the 200 scheduled towns there are 44 in which water-closets are general, 75 in which water-closets exist in considerable number, though privies are still much used, and 70 where privies very greatly exceed water-closets in number. Only 446 earth-closets are returned as existing in the whole of the 200 scheduled towns.

Removal of Refuse.—It appears that only in 11 cases is there a total absence of sewers to discharge liquid refuse. In those 11 cases the slops of the houses, the refuse of slaughter-houses &c., and the overflow from cesspools find their way into surface-streams, or are absorbed by the subsoil. At Paisley slops are thrown on the ashes to be removed by the public scavenger, and at Frome they appear, by the returns, to be purchased largely by cloth manufacturers. In these two instances only does there appear to be any profitable use made of the slops before they are finally discharged. All the remainder appear to have sewers for the removal of liquid refuse into which the excretal matter of 44 water-closeted towns is wholly discharged, while from 119 towns in which privies exist the excretal matter is partly discharged by the same means and partly by scavenging. In 3 cases the excretal matter is wholly removed by public scavenging, in 8 by private scavenging, and in 1 by both; and in 2 cases it is partly thrown into the surface-drains or ditches. In 25 towns the returns do not give any information as to the removal of excretal matter. The ashes are nearly universally removed by the public scavenger, though in a few towns the work is left to private action.

Storm and Surface-waters.—In the case of 149 towns out of the 200 these waters are admitted into the sewers; in nine instances, where new systems of sewerage have been adopted, the old sewers are entirely devoted to the discharge of surface-waters; in one instance special sewers are appropriated to the same purpose, while in 11 other instances the old surface-channels are used. In 25 cases more than one of the above systems are practised, and in the remaining 5 instances no return has been made. It will be seen, by a close examination of the tabular statement, that in many instances the sewers have to receive an immense body of water in

times of heavy rainfall. It occasionally happens that an inch of rain falls in twenty-four hours, and in certain seasons and under certain conditions half that quantity makes its way to the sewers in the same period. Two instances recorded in the schedule will serve to show the extent to which a sewerage system may be tried by such influx. In the Nottingham district, where it appears from the return there is a surface of 1870 acres tributary to the sewers, and where the annual rainfall is 25 inches, there fell on the 18th of September last (since the Committee has been sitting) 2·14 inches of rain. If at this time half the quantity reached the sewers, about 45 millions of gallons of surface-water would have had to be discharged by the sewers or storm overflows; and this would be more than eleven times the ordinary flow of the sewage, and thirteen times the water-supply. At Dundee, where the surface contributing to the sewered area appears to be 2120 acres, and the average annual rainfall the same as at Nottingham, viz. 25 inches, there fell in the same month (on the 12th of September, 1869) 1·70 inch of rain. If half of this quantity reached the sewers they had to discharge upwards of 40 millions of gallons from this source alone, equal to more than thirteen times the water-supply of the town. It is more than probable, however, that, although the returns show the contributing surfaces to be as much as stated, the actual quantity is less; but the figures serve to illustrate the difficulty to be contended with by the sudden admission into the sewers of such large bodies of water, and which only serve a good purpose when the sewers require flushing.

Subsoil Waters.—The removal of subsoil water from beneath and about dwellings having been shown by Dr. Buchanan in the 9th Report of the Medical Officer of the Privy Council to be of the highest sanitary importance, it has been deemed desirable to trace as far as possible the means by which local authorities have effected this object. The returns, which are very imperfect upon this point, show, as far as they go, that about 100 out of the 200 towns drain the subsoil by the sewers, which carry away the liquid refuse of their districts. The importance of this branch of the inquiry will appear when it is remembered that, having become mixed with the sewage, the subsoil water must be treated in the same way as the sewage itself. This consideration becomes greater in those cases where the discharged quantity has to be lifted by mechanical power at a never-ceasing cost. One or two instances given in the schedule will illustrate this. Torquay, a seaboard town with (according to the returns) about 20,000 inhabitants and a water-supply of 30 gallons per head, amounting on the whole to 610,000 gallons per diem, discharges 1,600,000 gallons of sewage a day, the addition of subsoil water being apparently in the proportion of 1·62 to 1, and the sewage discharged being equal to 80 gallons per head of the contributing population. In this instance, therefore, if the Local Board of Torquay should determine to raise and utilize their sewage instead of discharging it into the sea, they will have to pay £1 12*s.* 5*d.* for the raising of subsoil water for every £1 expended in raising the sewage. The river-side town of Leamington affords another example. This town has, according to the returns, a population the same as Torquay (20,000), and a water-supply of 400,000 gallons a day. The quantity of sewage discharged into the river is 1,000,000 gallons, the difference between the water supplied and the sewage discharged being 600,000 gallons, or 150 per cent. In the case of Hertford, where the water-supply is returned at 61½ gallons per head daily, amounting to 184,500 gallons per diem, the discharge from the sewers is returned at 1,750,000 gallons. This quantity is conducted, after lime

treatment, into the river Lee, above the intake of the East-London Waterworks Company. In this case the discharge from the sewers is, according to these figures, $9\frac{1}{2}$ times the quantity of water delivered to the houses of the town.

Ventilation.—The information afforded by the returns upon this point is very deficient, owing to the fact that very few instances exist in which any thing has been systematically done.

Disposal of Sewage.—The largest quantity of water discharged per head is that of Hertford, just mentioned, which amounts to 257 gallons. In many other cases a very much larger quantity is discharged from the sewers than can be accounted for by the water-supply, as will be seen from the following collected instances:—

Name of town.	Water-supply per person.	Discharge per person.
	gallons.	gallons.
Hertford........	$61\frac{1}{2}$	257
Burton-on-Trent.	..	175
Blackpool	7 with private supply in addition.	154
Dover..........	50	143
Enfield	33	89
Torquay........	30	80
Batley	20	70

Of the 189 towns and districts having systems of sewerage, 143 discharge their sewage without any treatment whatever; in 17 instances the sewage is simply filtered before discharge, in 7 instances it is chemically treated, and in 17 cases recourse is had to irrigation, whilst in 5 instances the system of disposal includes more than one of these methods.

Scavenging.—Much interesting information has been given in the returns with regard to the cost of scavenging and the returns obtained from the sale of ashes and excretal and other solid refuse. In only two cases among the returns from English towns is any profit realized, and these are Fareham and Stockton-on-Tees. At Stockton-on-Tees, with a population of 23,000, the return gives a profit of £100 a year. At Fareham, where there is a population of 6200, the refuse is sold to a contractor, who agrees to collect both house and street refuse, and to remove the sewage from the privy and closet cesspools when necessary, paying the Board £7 a year only. In Scotland, one instance only is recorded in which a profit is obtained, viz. Dundee, where £630 a year is made. In all other recorded cases the scavenger receives a payment in money as well as the refuse for doing the required duties. The greatest losses are experienced at Liverpool, where the scavenging costs £41,866 a year, or 19·7*d.* per head, and at Scarborough, where it costs £2050, or 22·4*d.* per head. At Malvern the cost amounts to 18·0*d.* per head; at Oldham, 13·1*d.*; at Bradford, 19·3*d.*; at Rochdale, 11·2*d.*; at Bridgenorth, 10·2*d.*; at Torquay, 10·2*d.*; at Newcastle 17·5*d.*; at Cardiff, 11·3*d.*; at Llanelly, 15·3*d.*; at Aberdeen, 11·2*d.*; and at Edinburgh, 11·7*d.* per head per annum.

The schedule is still very incomplete. If perfected in all its details, much valuable information would be collected, which would be found useful to the sewer authorities of towns throughout the kingdom.

B.

The district of Bury, with the township of Elton, in the county of Lancaster, is governed by a local Act, dated 27 July, 1846, 9 and 10 Victoria, Cap. CCXCIII., and embraces an area of 2692 acres, the number of inhabitants being about 40,000, and the annual rateable value of the district £123,467.

The town has a general system of scavenging for the removal of solid excreta, solid house-refuse, and street-sweepings, and a system of underground sewerage for the removal of liquid house-refuse and surface-water. There are 6500 houses in the district, 3859 privies, 1922 ash-pits, and only 153 water-closets.

The provisions for the collection and disposal of the solid excreta and house-refuse are evidently deficient. In the better class of houses each house has at least one privy; but the lower classes are very badly provided with them, and in one instance no more than 2 privies had been provided for the use of 20 cottages, a state of things worthy of the attention of the local Inspector of Nuisances.

No special treatment is practised previous to the removal of the contents of the privies, beyond the addition of ashes. This accession of ashes, together with the necessity of conducting its removal at night, materially reduces the value of such mixture as a manure, and the whole quantity only yields an annual return to the Commissioners of £100.

From the inconvenient positions of many of the ash-pits, together with their defective construction, the removal of the night-soil is rendered somewhat difficult and expensive. The ashes when not used for privies are generally sifted and employed in filling and levelling in the formation of new streets and footpaths; and it is even alleged that they are also so used in many cases after mixture with night-soil, which, no doubt, from a contractor's point of view, is good binding stuff.

The street-sweepings are also removed by scavenging, and cost the Commissioners not less than £629 11*s.* 8*d.*, while, from the want of some yard or other storage ground, they have to be disposed of to farmers at their own price, and only yield the insignificant return of £25 to £30 per annum.

The sewers are all of ample capacity to provide both for the usual daily flow of sewage and for surface-water due to the average rate of rainfall, which is 40 inches; and further, for the exceptional contingencies of storms, which produce as much as 1 inch per hour.

The sewers are built in hydraulic lime, and the pipe-drains laid with puddled joints, so as to prevent percolation of subsoil-water into the sewage, or leakage of sewage into the soil. No instance of deposit has taken place in any of the sewers, and flushing for the removal of deposit is consequently unnecessary.

The water-supply is constant, and is derived from catch-water reservoirs of the Bury and Radcliffe Waterworks Company, situated at Holden Wood, about eight miles above Bury. The Water Company supplies by meter to the Railway Company and to general trade consumers about a quarter of a million gallons per diem, and the same quantity to the town for domestic consumption. It is in both cases supplied unfiltered, and is at times perceptibly discoloured and disagreeable to the palate.

Analysis of Water supplied to the Town of Bury for domestic use.

	In 100,000 parts.						Total hardness 7·98.	
	Solid matter in solution, dried at 100° C.	Suspended matter.	Chlorine.	Ammonia.	Albumenoid ammonia.	Nitrogen, as nitrates and nitrites.	Permanent.	Temporary.
Water supplied for domestic use...	7·40	Trace.	1·10	0·0005	0·014	0·046	6·66	1·32

The principal outfalls from which the bulk of the sewage is discharged are three in number; there is also a minor outfall near Bury Bridge. The respective discharges from these outfalls are shown in the following Table:—

Little Bridge discharging into the River Roch:—

	gallons.	galls. per 24 hours.
per day of 15 hours..........	249,480	
per night of 9 hours	88,452	
		337,932

Bury Bridge, discharging into the River Irwell:—

per day of 15 hours..........	48,575	
per night of 9 hours	29,185	
		77,760

Hinds Outfall, discharging into the River Irwell:—

per day of 15 hours..........	40,500	
per night of 9 hours	18,144	
		58,644

Bury Bridge Abutment, discharging into the River Irwell:—

Discharge for the 24 hours..............		20,160
Total gallons per 24 hours		494,496

Remarks by a Sub-Committee, consisting of Messrs. Grantham (*Chairman*), Corfield, Hope, and Williamson.

Bury was selected as one of the towns to be investigated, because it is a town where it may be said there are no water-closets; and the Committee having heard a good deal of the efficiency and even economy of the Lancashire ash-pit system for the removal of fæcal matter and other solid refuse, desired to possess themselves as soon as possible of the facts in connexion with this system as regards some one typical town. Another reason for the selection of Bury was that the almost total absence of water-closets would enable the Committee, by examining the liquid escaping into and discharged from the sewers, to judge whether any of the proposed methods of intercepting fæcal matter from the sewers (such, for instance, as the earth-closet) would in themselves be either a solution of the great "sewage question," or even one considerable step towards it.

The figures obtained in Bury of the ash-pit system, as carried out there, prove that, financially, it is, so far as Bury is concerned, a total and complete failure, as the gross return is only a little over one halfpenny per head of the

population annually. Of course it is not fair to judge of a general system from a particular instance, and the subject should be further investigated.

The fact that the ashes of Cambridge, with a population of 27,000 as against 40,000 at Bury, sell, together with the street-sweepings, but without any fæcal matter, for £200 annually, while the ashes of Bury mixed with almost the entire fæcal matter of the town produce annually only £100, and the street-sweepings only another £25, is worthy of remark.

The subjoined analyses of Bury sewage show that although the sewage from a town managed on the Bury system is weaker and therefore less valuable and proportionately more difficult to deal with than the sewage from a water-closeted town, yet that its purification is just as imperatively necessary.

Bury Sewage.—Collected August 11.

	In 100,000 parts.					
	Solid matter in solution dried at 100° C.	Suspended matter.	Chlorine.	Ammonia.	Albumenoid ammonia.	Nitrogen, as nitrates and nitrites.
Bury Bridge outfall	56·00	....	10·79	2·554	0·100	None
Little Bridge outfall	72·20	64·84	13·63	3·834	0·198	None
Hinds outfall	42·50	3·74	4·83	0·884	0·052	None
Collected August 15 and 16.—Night.						
Bury Bridge......	44·80	Very small amount	5·18	0·459	0·034	None
Little Bridge	38·60	Very small amount	4·69	0·760	0·040	None
Hinds outfall	38·00	Very small amount	3·76	0·099	0·030	None

With respect to the character of the sewage, it was found to run very clear and almost colourless from 3 A.M. to 6 A.M., after which hour it began to alter its character perceptibly; and at 8 A.M. it assumed a thick and soapy consistency, and from that hour to 12 noon it was invariably "very thick, black, and greasy," and "smelt very bad;" and on the Friday morning it was "red, as if with blood." On the 11th of August the samples were taken between the hours of 9 and 11 A.M., and on the 16th at 5 A.M.

Cambridge.

This is a town having a complete system of underground sewerage for the removal of sewage with a general water-supply, and, with the exception of the colleges, a general adoption of water-closets.

The Borough of Cambridge is governed by Improvement Commissioners under the Acts 28 Geo. III. C. 64 and 34 Geo. III. C. 104.

The area of the district under the jurisdiction of the Commissioners is about 3470 acres; the number of inhabitants at the present time is about 27,000, occupying about 6000 houses. The annual rateable value of the district is £125,226, and the colleges contribute one-fourth of the expenditure of the Commissioners.

There is a constant supply of water to the town pumped up by a water

company from springs at Cherry Hinton into a covered reservoir of a storage capacity of 1,000,000 gallons, situated about three miles from Cambridge.

The average daily supply to Cambridge by the company is 427,000 gallons,—that is to say, 280,000 gallons for the domestic consumption of 21,500 persons, or 13 gallons per head, and 147,000 gallons for trade consumption, of which the railway company takes 68,500, general trade 60,500, and watering streets 18,000 gallons.

There is also a supply from private sources, including Artesian wells sunk to the Gault, estimated at 50,000 gallons per day; and "Hobson's Brook" supplies during the dry weather season about 789,000 gallons per day to the town. It rises at a spot called Nine Wells, about three miles from Cambridge, and terminates in a head near the Botanic Gardens, from which point it is distributed to different parts of the town, namely,—first to the public conduit or drinking-fountain in the market-place; secondly, by two open channels or "runs," one on each side of Trumpington Street; thirdly, by pipes and open course to the Hospital and Pembroke College; and, fourthly, along Lensfield Road to Hyde Park Corner, thence in two open street-channels along St. Andrew's Street, and also to Emanuel and Christ Colleges. The water from the two channels is discharged constantly into the sewers at Trumpington Street and St. Andrew's Street, and can, when desired, be diverted into the sewers at a higher level for the purposes of flushing. These open channels are each provided with a silt-pit just previously to their entering the sewers. There is also an ingenious arrangement for flushing by means of the water supplied to the public drinking-fountain in the market-place. It consists of a large octagonal chamber surmounted by a central fountain, from which the water overflows by eight drinking-spouts into a basin that discharges itself into the chamber beneath; and the arrangement permits of the periodical discharge of the contents of this chamber to flush the sewers leading from the market-place. The sewers of ninety streets and lanes are flushed quarterly from the water company's works. The street-gulleys are also periodically flushed or washed by means of water-carts in dry weather; and provisions of minor importance are also made to carry on the flushing. A tank in Trinity Place filled from an Artesian well, another tank in St. Andrew's Court, opposite Emanuel College, and a smaller cast-iron tank in King's Arms Court, King Street, are all used for flushing once a week. The contents of these sinks are discharged into the sewers by penstocks.

All houses are provided with water-closets without any system of ventilation, the pipes being trapped by earthenware or lead D-traps. It was stated that some closets were ventilated by means of the water-pipes, and these, which were supposed to act, were found to be totally inefficient; but an attempt is being made to improve the system in new buildings. The only instance in which earth-closets have been adopted is at Queen's College, where there are two.

Most, if not all, of the colleges on the banks of the river preserve arrangements of the most primitive possible description overhanging the classic waters of the Cam, identical in construction with those that were in existence when the great author of the 'Principia' discovered the laws of gravity. Those of the privies which do not overhang the river are provided with cesspools which overflow directly into the river; and many of these are in a most offensive condition. Finally, the accommodation of this nature, such as it is, which is provided in this great University exists only in the proportion of 7·4 per cent. of the residents, or less than one for every thirteen persons.

Nearly the whole area is provided with a general system of underground

sewerage for the removal of water-closet and liquid house-slops, of rain-water from roofs of houses, yards, and streets, there being about twenty-one miles of sewers, which are calculated to meet the demands of the average annual rainfall, but not of storms nor of periods of exceptionally heavy rains.

The greater portion of the ashes is collected by the Commissioners daily, and, together with the street-sweepings, is sold for the sum of £200 annually. A small portion only is collected by private individuals. The cost of collection could not be ascertained.

The area contributing surface-water is approximately the area of the district, 3470 acres, and the average annual rainfall is 22 inches. The roadways of the streets are macadamized; they incline from the centre to the curbs at a rate of about 1 in 100, and are provided with gulleys connected with the sewers.

The subsoil is mostly gravel from 3 to 10 feet deep, overlying a bed of gault from 120 to 135 feet thick. It was formerly saturated, but the sewerage has drained the upper subsoil and dried many of the wells that previously existed. Inquiries were made into the state of some of the wells belonging to private houses, and it was found that they were all contaminated by sewage, owing to their proximity to the sewers in the streets and to the drains on the premises, so much so, that the water cannot be used for drinking but only for washing.

The old sewers are of irregular forms, but the recent sewers are egg-shaped or circular. They discharge at twelve separate outlets into the river Cam. The inclination of these sewers varies from 1 in 120 to 1 in 2000. Deposit has taken place to a considerable extent in the Hills Road sewer, with an inclination of 1 in 2000, the deposit being, at the date of the examination, $7\frac{1}{2}$ inches thick, and the sewage running over it 6 inches deep. The outlets of the public and private sewers are all under the level of the surface of the water in the Cam, consequently the sewage is backed up in the sewers for a considerable distance, and the subsoil is constantly saturated with both water and sewage in the lowest parts of the town. The authorities obligingly offered to draw off the water of the Cam to enable the engineers to gauge and collect samples of the sewage flowing from the sewers; but as the bed of the river could only be kept dry for a short time, the results would have been unsatisfactory. Moreover, as the water which is backed up in the soil would be discharged by degrees through the sewers, no correct result could have been attained.

There are two gaols (county and borough), a workhouse, a hospital, and an asylum, all of which are connected with the sewers. There are no factories nor special trades, but the slaughter-houses send their liquid refuse into the sewers, and this on killing days is highly charged with blood; the solids from this source are mixed with ashes and carted away.

Remarks by a Sub-Committee, consisting of Messrs. Grantham (*Chairman*), Corfield, Hope, and Williamson.

It is not the province of the Committee to prepare schemes for the sewerage, or for the drainage of particular towns, and as the inquiries of the Committee are still far from complete, it would be premature to make any suggestions either in this or any other case as to the best means of utilizing the sewage when collected; but it is manifest from the foregoing Report that the sanitary conditions of Cambridge, as regards its sewerage and drainage, are exceedingly bad, and the low level of the greater portion of the town must make

improvement both difficult and expensive. The chief general importance of the inquiry into the conditions of Cambridge is the proof thus obtained of the pollution of wells, and therefore of subsoil, by the agency of pervious street- or house-sewers constructed in their vicinity; and the Sub-Committee desires to give expression to the conviction forced upon it in the course of its inquiries, that all sewers properly so called (that is to say, drains into which refuse from human habitations is admitted) ought to be constructed of materials which are altogether impervious, and that a separate system of pervious drains, similar to agricultural drains, should be constructed where necessary to dry the subsoil. The Sub-Committee is of opinion that the further construction of pervious sewers should be prohibited by Parliamentary enactment.

C.—*Breton's Farm near Romford.*

The town of Romford, in the county of Essex, is about twelve miles east of London, and is situated on the so-called "River" Rom, which is now, however, only a brook. The Rom rises in the high grounds of Hainault Forest and Havering-atte-Bower, and, after passing through the town, flows into the River Thames to the east of Dagenham.

The soil upon which the town rests is chiefly light loam, in places approaching brick-earth in character, and underlain by flint-gravel, which yields water freely.

The population is about 8000, but the refuse of only about 7000 is discharged entirely into the sewers, although the whole population is within the area provided with underground sewers. The refuse of the remainder is discharged partly into cesspools, the contents of which are removed by farmers.

The ordinary dry weather sewage discharge from all sources is 247,000 gallons daily.

The number of houses within the district is about 1200, and the rateable value is assessed at £23,341, the present annual rate being £840.

The workhouse, which is separated from the town by the railway, and lies to the south, has from 300 to 400 inmates, the solid refuse from whom is treated in privies with lime and ashes, the liquid passing to the sewers.

The town is supplied with water by the South-Essex Water Company; but there are many wells in it, and the great "Romford Brewery" is supplied by its own wells.

The surface-water is, for the most part, conveyed into the town sewers, but a part of it is discharged into the River Rom by the old drains. Through defective work, it is probable that a large amount of subsoil water finds its way, at times, into the sewers, and in dry weather a converse leakage of sewage into the subsoil is also probable. The sewers having little fall, are flushed by the Rom occasionally, but they are blocked at times by the sewage-deposit in some particularly flat places, which are flushed and cleansed by hand twice a year at a cost of £12 annually. There is a storm overflow which discharges into the Rom. The sewers are ordinary egg-shaped brick and glazed stoneware pipes. There are ventilators in the streets and roads.

The "sewer authority" is the Romford Local Board of Health, constituted under the Public-Health Act of 1848.

The discharge of the sewage into the Rom immediately below the town polluted it to such an extent, and it became so great a nuisance, that the Court of Chancery granted an injunction restraining the further discharge of the sewage in that manner.

The following is an analysis of an average sample of the sewage as flowing from the town:—

	In 100,000 parts.				
	Solid matter in solution dried at 100° C.	Suspended matter.	Chlorine.	Ammonia.	Albumenoid ammonia.
Average of eight samples of sewage taken at Romford, September 3 and 4	98·5	19·75	14·5	1·2	1·0

The Board of Health at first resorted to temporary means of disposing of the sewage by pumping it on to lands adjacent to the outfall, but eventually prolonged their outfall sewer to a farm in the parish of Hornchurch, named "Breton's," containing 121 acres, which they purchased for the purification and utilization of the sewage by irrigation.

This farm is situated at a distance of two miles from the town, and the sewage flows to the lower portion of the farm by gravitation. At the farm the Board have constructed a tank, into which the sewage is discharged by the main sewer. They have also erected two steam-engines of eight horse-power, by which the sewage is pumped up to a height of about 25 feet into iron troughs supported on wooden tressels, which convey the sewage to all parts of the farm, by discharging it either directly into gutters or grips formed on the ridges of the "lands," and out of which the sewage is distributed right and left down the slightly inclined slopes of the "lands," or, in the first instance, into concrete "carriers," raised by earth banks to a height intermediate between the height of the iron troughs and the level of the ground.

The whole farm has been systematically laid out by the tenant in 30-feet "lands" or "beds," the carriers being placed so as to take advantage of the natural fall in the ground.

The soil of the farm is very light and sandy, containing many stones; and gravel, which forms the subsoil, is found at a depth of from 8 to 20 inches. The gravel is ordinary yellow flint-gravel, but it is interspersed with patches of yellow and white sand, and even contains in places a slight admixture of clay. An analysis of the soil is subjoined (see p. 70).

About 85 acres of the farm, which are above the level of the tank, have been underdrained by pipe-drains 50 yards apart, and from 5 to 6 feet in depth, in such a manner that the water from the drains can be discharged into the sewage tank if required in dry weather, or at pleasure into the river Rom. There are roads communicating with different parts of the farm laid out so as not to interfere with the complete distribution of the sewage by the iron troughs and carriers.

The construction of the sewer and tank, and erection of the engines, pumps, and iron troughs, have coast the Local Board the sum of £4300.

The Board has let the sewage upon lease for £600 a year, the arrangement being that the tenant pays this sum in addition to the rent of the farm for the sewage pumped up and delivered into the troughs, from which point the tenant is responsible for its proper disposal, and is bound to hold the Board harmless from any actions for nuisance.

The accompanying plan and sections show the manner in which the farm is laid out and the sewage distributed.

The entire farm was fallow all the winter, and was only gradually brought under cultivation in spring and summer.

Of Plot A (Plate I.), the beds from 1 to 10, both inclusive, were sown with Italian rye-grass on March 19th, and beds 11 to 20, both inclusive, were sown a week later. From these together, equal to 6·68 acres, five crops have already been cut, and the sixth is now growing. The average weight of the crops has been, however, small, not exceeding $6\frac{1}{2}$ tons each per acre, owing to the dense growth of weeds (especially "chickweed"), which almost smothered the grass, the farm having been long neglected, and the ground being full of the seeds of weeds. Bed 21, containing ·39 of an acre, was sown on April 27th with "Savoy" cabbages for planting out. Beds 22 to 28, with the lower half of 29, which were chiefly old meadow-land broken up, and included two lines of old hedge-row, could only be imperfectly cultivated; they were, however, sown on the 27th of April with seeds of a small kind of cabbage, known as bunching-greens, or rosette cabbage, more properly coleworts. These beds comprised 3·5 acres, and besides furnishing plants enough for 7·25 acres in plots C, E, N, and P, produced 470,000 plants for sale, which realized £35 5*s.*, and further supplied 3240 full-grown plants for market, which realized an additional sum of £4 10*s.*

The whole of Plot A will shortly be filled with winter crops.

In Plot B, beds 1 and 2, equal to 0·972 of an acre, were sown with early "horn" carrots, which were sold for £19 10*s.* in the ground. The carrots were sown on March 25th, and were taken out of the ground in the first week in August; these beds are now sown with Italian rye-grass for cutting next year. Bed No. 3, 0·486 of an acre, was planted with potatoes on April 2nd; the potatoes were of three kinds—the Bovinia, a large cattle potato, the early Rose, a new American variety, and the ordinary Dalmahoy. The potatoes are not yet all off the ground, but they appear particularly fine. Bed No. 4, equal to 0·486 of an acre, was sown on the 2nd of April with "broad Windsor" beans, which were sold for £4 10*s.*, the buyer picking them and leaving the straw.

Beds No. 5 to 8 inclusive, equal to 1·96 acre, were sown in the first week in April with "Champion" peas for eating green, which were sold in July for £30, the buyer picking them and leaving the straw.

Beds 4 to 8 inclusive are now sown with Italian rye-grass. Beds 9 to 17 inclusive were sown on April 19th with Italian rye-grass, and the fifth crop is now being cut. It should here be mentioned that the rye-grass not required for the horses on the farm has obtained a ready sale at £1 per ton on the ground, partly to the neighbouring farmers for their horses, and partly to London cowkeepers.

In Plot C, beds 1 to 8 inclusive, 2·75 acres were planted on July 2nd with greens transplanted from Plot A, which are now being sold at about £25 per acre. Beds 9 to 23 inclusive, about 4 acres, were sown with white turnips on May 6th; but Plot C, being exceedingly stony, little better than a bed of shingle, the slope below the contour line exceedingly rapid and steep, and comparatively few of the seeds surviving the excessive drought and frosty nights, the result was that only £25 could be obtained for this crop in the ground.

The major part of Plot D, equal to 10·7 acres, was drilled with mangold wurzel as late as May the 14th, and the crop nevertheless promises to yield from 40 to 45 tons per acre. The lower part of plot D (2 acres) was

planted with drumhead cabbages, interspersed with bunching-greens, in the first week in August.

Plot E was a difficult piece of ground to lay out, involving much labour, and was worked at only from time to time, as the labour and horses were available. Beds 1 to 10 inclusive (2·961 acres) have just been sown with winter onions. Beds 11 to 14 inclusive (1·026 acre) were sown on August 19th with early York cabbage-seed for planting out. Beds 15 to 21 inclusive (1·712 acre), on July 16th were planted with greens from Plot A, and bed 22 (0·165 acre) is still vacant.

Plot F is not yet properly laid out, and a great part of it is not yet under cultivation; the remainder, about 2¾ acres, was sown with onions on March 19th, and some have been sold at the rate of £36 per measured acre in the ground.

In Plot G, bed No. 1 (0·2385 of an acre) was sown with parsley on June 24th; beds 2 and 3 (0·477 of an acre) with sugar beet-root on June 4th; beds 4 and 5 (0·477 of an acre) with crimson beet-root for table in June; bed 6 (0·2385 of an acre) with white brocoli-seed for planting out; bed 7 (0·2385 of an acre) was sown with "Savoy" cabbage-seed on July 16th; bed 8 (0·2385 of an acre), on April 23rd, with four kinds of carrot-seed; beds 9 and 10 (0·477 of an acre) were sown on April 25th with four kinds of mangold-wurzel seed. These last three beds promise to yield some magnificent specimen roots for exhibition. Beds 11 to 15 inclusive (1·1925 acre) were sown with parsnips on April 28th, and, the seed being bad, failed in many places; there are, nevertheless, many fine roots. Bed 16 (0·2385 of an acre) was sown on May 7th with spinach. It was cut on the 5th of June, and realized at the rate of £22 per acre. It was broken up and again sown with spinach on the 16th of June; the price having fallen, this crop was given to cattle. The bed was then ploughed and sown on the 23rd of August with Tripoli onions for planting out in spring. Bed 17 (0·2385 of an acre) was sown on the 17th of June with spinach, some of which was sold, and the rest given to cattle. The bed was then ploughed and sown on the 9th of July with maize for cutting green as fodder. Bed 18 (0·2385 of an acre) was planted on the 26th of May with East Ham cabbage and cauliflowers. They have been sold at the rate of £27 and £25 per acre respectively. Bed 19 (0·2385 of an acre) was planted on the 21st of May with white cos lettuces, which were, for a particular purpose, kept in the ground rather too long, but still produced at the rate of £24 per acre, after which the bulk of them were given to cattle. This bed was ploughed and sown on 23rd of August with Tripoli onions. Bed 20 (0·2385 of an acre) was planted with brown cos lettuces on the 21st of May, which, being too late, were given to cattle. It was then ploughed and sown on the 23rd of July, when the rye harvest of the district was entirely over, one half with oats and the other half with barley, with a view to ascertain whether it would be possible to ripen two crops of cereals on the same ground in one season. They were expected not to ripen before October, therefore the result is as yet unascertained. Bed 21 (0·2385 of an acre), also brown lettuces given to cattle, followed by white cos lettuces, which realized at the rate of upwards of £30 per acre, followed again by winter spinach. Bed 22 (0·2385 of an acre) contains some patches of red clover, Jersey cabbages, yams (*Dioscorea batata*), and turnips, all of which are vigorous and healthy.

In Plot H, beds 1 to 5 inclusive (1·3162 acre) were planted on July 20th with sprouting winter brocoli. Beds 6 to 9 inclusive (1·458 acre) were planted on July 20th with Brussels sprouts. Beds 10 to 17 inclusive

(3·6 acres) were sown on August 24th with East Ham cabbage-seed for planting out. Bed 18 (0·55 of an acre) was planted with celery in the first fortnight in August, and beds 19–25 inclusive (3·332 acres) were filled gradually with mangold wurzel transplanted from D and C, commencing on June 13th, and continuing for more than a month.

Only the upper part of Plot I (1·166 acre) has been as yet laid out; this was sown on May 6th with broccoli and Savoy cabbage-seed for planting out. Upwards of £30 worth have been sold from these beds, and they are now thick on the ground. The rest of Plot I (5·184 acres) was sown with onions on the same day as Plot F, namely, March 19th. These two plots of onions comprise the greater part of one of the old fields which was surrounded with a huge ditch and hedge, full of great trees; it had been roughly but heavily sewaged in winter, and it was the intention not to apply any more sewage to it until the onions were off the ground; but the drought was so severe and the ground became so dry, that it was necessary to give them moisture to save them, and they received one dressing of sewage in May and another in July. Part of Plot I has also been sold at the same rate of £36 per acre in the ground as obtained for F.

In Plot K, beds 1 to 5 inclusive (2·397 acres) were sown on May 28th with white runner beans, which have borne well, and are not yet over. Beds 6 to 10 (2·047 acres) were planted on July 14th with Walcheren cauliflower.

Plot L was an old meadow, which was heavily sewaged last summer, and was broken up in winter and sown with white Poland oats on April 9th. In many places the seed never came up, owing to the severe drought, but the crop nevertheless gave a return over all of five quarters one bushel to the acre.

In Plot M, bed 1 (0·387 of an acre) was partially planted with drumhead cabbages on June 2nd, and filled up with kohl rabi; bed 2 (0·387 of an acre) was planted with Walcheren broccoli; the rest of Plot M (2·935 acres) was planted on June 25th with Savoy cabbages from bed 21, Plot A.

In Plot N, bed 1 (0·252 of an acre) was sown on April 27th with a new kind of American oats, which were cut on August 22nd, and yielded twenty-eight bushels, equal to fourteen quarters, per acre. At the beginning of June this crop was seriously damaged and in danger of being destroyed by the ravages of the *Oscinis vastator*, one of the smallest but most destructive of those "grubs" and "wireworms" which at times cause such injury to cereal crops in this country. The remedial effects of sewage irrigation under similar circumstances having been previously observed elsewhere, two heavy dressings of sewage were applied to this bed during two successive days, the result being that the grubs were entirely destroyed and the greater part of the crop was saved. It is proposed to conduct some experiments to ascertain whether this result could be accomplished by the use of pure water, or whether with the physical effects of immersion sewage applied in this way, combines the action of some agent or agents which act as a specific poison to organisms of that type. Beds 2 to 4 inclusive (0·756 of an acre) were sown on June 1st and 2nd with six kinds of maize specially imported from the United States, as likely to suit the climate of England; the maize is now from 5 to 9 feet high, appears to be ripening, and promises a very heavy yield. Bed 5 (0·252 of an acre) was sown on June 4th with a new kind of Brome-grass, introduced from Australia by Messrs. Sutton and Sons, and named by them *Bromus odoratus*. It has already been cut three times, and has yielded at the rate of seven to eight tons per acre.

This grass being a perennial, it will be interesting to observe for how long it will retain its present extraordinary rapidity of growth, and whether, under such forcing treatment as sewage irrigation, it will not cease to be perennial. Bed 6 (0·252 of an acre) was first sown with tobacco; but for some unascertained reason the seed failed, and it was broken up and resown on July 9th with maize for cutting green. Beds 7 and 8 (0·504 of an acre) were sown with sea-kale on June 10th, and broccoli plants were put in between the rows of sea-kale in August. Beds 9 and 10 (0·522 of an acre) were planted with East Ham cabbages on June 16th from seed raised in the garden; these two beds have been sold at the rate of £25 per acre in the ground. Beds 11 to 16 inclusive (1·566 acre) were planted on June 20th with bunching-greens from Plot A; these have been sold at £21 per acre in the ground.

In Plot O, beds 1 to 11 inclusive (4·12 acres) were sown on April 4th with "intermediate" carrots, part of which have been sold for £20 and £21 per acre in the ground, and part (washed and bunched and sent to market) realized £41 per acre. Beds 12 to 17 inclusive (2·223 acres) were sown on April the 5th with onions, which were bunched and sent to market, where they realized £46 per acre.

Plot P, which is a gravel-pit, not yet wholly obliterated, has been partially planted with greens from Plot A.

Plot Q has as yet had nothing in it.

Plot R, an old meadow heavily sewaged last summer, and broken up last winter, was planted with Dalmahoy potatoes on March 25th; the crop was very fine for the season, and realized £25 per acre.

Plots S and T are still waste and uncultivated.

Plot U is an old meadow, which has been irrigated by means of moveable troughs; it contains 6·14 acres, and has already yielded two crops of hay, and a third is now ready to cut.

Plot V is also an old meadow of 3·5 acres, and is used as a playground for the horses.

Agricultural experiments necessarily require a very long time to be carried out, and a period of twelve consecutive months is the shortest possible space of time in which any thing like a fair result can be looked for. It is not possible, therefore, to compile from the past observations of the Committee, during so short a period, any thing that would not be very misleading in the shape of a debtor and creditor account, whether as to the pecuniary expenditure and returns of the farm, or as to the expenditure of manure distributed by means of the sewage and the returns in the crops estimated chemically. Nevertheless, from the foregoing figures, it will be seen that sewage in its liquid state can be practically applied to apparently every kind of crop. This was no doubt pretty well ascertained by previous experiments elsewhere; but in no case have these experiments been so systematically and carefully observed, and so little liable to be affected by disturbing causes. It is therefore already one step gained towards the solution of the sewage question that these experiments have been conducted under the eyes of the agent of the Committee, as well as under the occasional observation of some of the members of the Committee.

The Committee hope to obtain data of greater value and importance from the accurate record of the experiments and practice on the farm during a future complete year, and some appliances have recently been, or will shortly be, brought into use on the farm which will very greatly facilitate such observations. The soil of by far the major part of the farm (Plots A,

B, C, D, E, G, H, K, M, N, O, P, and Q) is composed of a very loose open sand and gravel overlying coarser sand and gravel in every case; and in many places it has been impossible, in the laying out of the land, to prevent the yellow subsoil from being exposed. The accompanying analyses of the soil taken from a part which had not been sewaged will show its extraordinary poverty in organic matter; and if this is taken into account, and if it is also recollected that all the crops were got into the ground during the late almost unprecedented drought, and that from repeated workings and shiftings the soil was in an abnormally dry condition, it will be seen at once that it was necessary in every case to apply a much larger quantity per acre of moisture and manure in the form of sewage for starting the first crops than would ever be necessary under ordinary conditions of farming. Moreover, the tenant, while bound so to utilize the whole of the sewage of the town of Romford as to prevent the pollution of the river, has only a limited area of land on which to apply it, and therefore he cannot avoid putting on in many cases more sewage (that is, manure) than would otherwise be necessary; but as such unusual conveniences exist on the farm for measuring, not merely the sewage going on to the farm, but also the effluent water escaping, it will be quite possible to ascertain during the ensuing twelve months exactly how much manure is placed upon the land, and very nearly with the same exactness, how much is utilized, and how much wasted. However, as absolute accuracy cannot be attained on so large a scale, and as the tenant is bound, as before explained, to apply a certain quantity of sewage over the whole area of the farm, whether his crops actually require it or not, he has constructed some large wooden boxes of 2½-inch deal carefully tongued and grooved at the joints and strongly bolted together with iron bolts. These boxes are 6 feet deep; they are filled with earth carefully taken so as to represent an average section of the farm, and the superficies of the earth in each box (in other words, the inside measurement of each box) is equal to ·001 of an acre. The boxes are sunk in a huge ditch on the farm, which has not yet been obliterated; and they are so packed round as to reduce to a minimum, quite inappreciable, the difference between their evaporation and internal temperature and those on or below the natural surface of the ground. The bottoms of the boxes have also been so constructed as to give a slight drainage towards the centre, and also towards one end. In the centre of each a small drain-pipe has been laid, and at the end of it a hole has been bored in the end of the boxes so as to admit of the free exit of the effluent water. These boxes, then, afford the means of carrying out experiments with accuracy, while they are yet upon a scale and under conditions which make them accord strictly with actual practice. Such experiments have never yet been conducted, and their value cannot be overrated, more especially as explanatory of the observations conducted as to the actual practice on the farm itself; for instance, it will be found that of the total amount of the manurial constituents of the sewage applied to the farm a certain quantity is wasted and escapes in the effluent water. The experiments in these boxes will at once prove whether such escape is due to the application of a quantity of manure in excess of the requirements of the plants and their power of assimilating it, or whether the waste of a certain percentage of manure applied when in a state of solution by irrigation is a necessary defect of the system; that is to say, whether, when quantities of manure are applied only sufficient for the chemical wants of the plants, it is nevertheless not in the power of the plants and the soil and the other agents at work to isolate that manure from the water in which it is dissolved, and to retain the whole

of it for profitable consumption. These box-experiments will, it is hoped, also afford data for ascertaining the amount of water evaporated from the surface of the ground under different conditions. They will, it is hoped, show whether or not sewage can be applied to fallow land, and so stored up in the winter for use in the growing season as to enable the farmer to purchase at all seasons.

It is hoped that they will further test the efficiency of intermittent downward filtration in purifying sewage.

The tenant entered into the occupation of Breton's Farm on the 29th of September of last year, but there were no appliances for distributing the sewage. There existed merely the main sewer from the town to the farm, the pumping-engines, and a small but quite insufficient underground iron pipe from the engine to a point in plot G, from which point there was further, running along the top of plot G, an earthenware pipe raised up on the top of an earthen bank some 3 or 4 feet in height. These appliances were, however, ludicrously insufficient, whether as to level or capacity, for distributing the sewage; and during the greater part of the time, from September 29 to May 18, the sewage was either not put upon the farm at all, being applied to other ground elsewhere, or it was simply allowed to stand in pools anyhow on plot F, I, and U, with the occasional formation of similar puddles in G and E.

Since the 18th day of May, however, the whole of the sewage has been applied to the farm; and during a great part of that time the whole of the effluent water escaping from the land above the contour-line of drainage has also been pumped back over the farm, while during the preceding thirty days, namely, from the 18th April to the 17th May, both inclusive, the night-sewage only was pumped on to the farm during the day, and, though very much weaker, was yet valuable as moisture.

But it is not possible to apportion this quantity with absolute exactness to the different crops grown. There are always four men superintending the distribution of the sewage, and it would not be possible to check the quantities distributed by them with absolute exactness unless by the employment of an assistant engineer to supervise each man; and this was an expense which the Committee did not feel warranted in incurring. However, several very accurate experiments were conducted to ascertain the capacity of earth laid out in beds of 30 feet wide for the absorption of liquid; and on the 19th March, a period when the land was in what may be considered an average state of moisture, the quantities of sewage which land broken up and stirred on the previous day to a depth of 9 inches, and also land consolidated by rolling, could respectively absorb.

The experiments were conducted in three different ways, so that the calculations may be relied on as being correct. The methods adopted were: first, the ordinary weir or notched board; secondly, a box with a sluice at each end which held an ascertained quantity, by which means the sewage flowing upon the land was subjected to actual measurement; thirdly, a weir was placed in one of the main carriers resembling in form an ordinary notch-board, but the square notch or opening in the centre was grooved, and a series of little sluices was fitted in, so that the opening could be filled up from the bottom and the water behind maintained at any required depth so as to give any desired head a pressure behind it. Then in one of the lateral openings in the carrier behind the weir was placed a smaller, but similar weir, also with a rectangular opening in the centre, the edges of which opening were likewise grooved; and into this groove fitted iron slides having

square holes cut out in their centre of different sizes. It will thus be seen that the methods in which the experiments were conducted gave three distinct and separate sets of data on which to base calculations; and it resulted that land in the state of moisture which existed on the 19th March and laid out in beds of 30 feet wide would only absorb, when consolidated, on the surface about 40 tons of liquid per acre, and when stirred to a depth of 9 inches on the previous day, about 90 to 110 tons per acre. By the word absorb is meant that no more than the above quantities could be applied without the formation of puddles at the sides of the beds. Of course, to lay down dogmatically that land under any given condition will absorb any exact number of gallons, or even tons, to the acre would be mere pedantry, and therefore it was sought in these experiments to ascertain what might be considered, after several different trials, to be the average figures. The questions what are the minimum and maximum quantities that can be absorbed by land abnormally saturated by heavy rains in winter when there is little evaporation, or abnormally dried by repeated agricultural operations performed in a period of drought, when there is a maximum of evaporation, have not been yet ascertained; but the state of the land on the 19th March may fairly be taken as an average condition: and this, after all, is more important than the observation of occasional extremes; and the box-experiments about to be conducted will afford an opportunity of making these further observations with far greater accuracy than could be attained on a larger scale.

If we divide the average daily quantity of sewage and effluent water (namely, about 1400 tons) pumped on to the farm during the period observed, and during which period the land was, as a rule, well stirred, by the figure of 100 tons, arrived at by the experiments conducted on the 19th March, we get 14 acres as the quantity irrigated every day; but this would not be correct, because there were at work the disturbing causes of the excessive drought and the artificial amount of evaporation induced by the great number of manipulations which the larger part of the farm had received in the process of laying out the ground; and, as a matter of fact, the average area irrigated daily from the 18th May to the 1st September has been a little over $5\frac{1}{4}$ acres. Then 0·34 being the point of saturation of those samples of the soil chemically examined and analyzed, it would follow that if we assume that the liquid would not penetrate during the few minutes employed in dressing the surface at any one part of the bed to a depth of more than 10 inches (although the land was cultivated to a depth of 20 inches), the maximum quantity of sewage that could be applied, supposing the soil to be not only abnormally, but even chemically dry, would be 384 tons per acre. In all probability, therefore, 400 tons per acre is the largest quantity that has ever been applied in any one dressing; and if we assume that the first dressing all over was at the rate of 400 tons per acre, that the second dressing was at the rate of 200, and that the subsequent dressings were at the rate of 100, we shall not be far from the truth.

Although, as has been explained, nothing in the way of a complete result, whether financial or chemical, can be obtained from the incomplete observations on the farm, it is not without interest to compare the results of some of the crops with others of the same kind grown in precisely the same soil, on the same tableland, and within a few hundred yards.

A small field of between 3 and 4 acres in the adjoining farm was sown with peas for picking green. These the farmer tried to sell on the ground for £8 an acre; but he was unable to sell them at all, and at last left them to ripen. They still remain unsold, and are estimated to be worth from £5 to £6 an

acre, while the straw was so stunted that there were not two loads from the whole area.

In the next field beyond the peas (farmed by one of the best agriculturists in the county, a man of superior education and agricultural knowledge, who has farmed the same land for years past with immense care, having planted small hedges here and there to give shelter and break the wind, and having grubbed up the old hedges, and having further collected the stones off the surface of the land, and who applies farmyard manure, guano, bones, &c. with both liberality and judgment) were sown onions, and these onions the farmer said that he would gladly sell for one-fifth of their cost.

Again, upon the small meadow at Breton's marked U, comprising altogether, after deducting ponds &c., only $5\frac{1}{4}$ acres that can actually be mowed, the two crops of hay already got in amount to 9 loads ($3\frac{3}{4}$ and $5\frac{1}{4}$ respectively); and a third is growing, which, with care and energy and the assistance of a large barn may easily be got in in the present month, is estimated as equal to the first, making a total of $12\frac{3}{4}$ loads in one season from $5\frac{1}{4}$ acres. The tenant of Breton's has a large meadow, about three miles nearer London, sloping down to a brook shaded by trees, and which ought to suffer less than most from drought; yet off an available area for mowing of 27 acres, he was only able to get 4 loads of hay, and there is scarcely any aftermath at all. In potatoes and carrots the figures run in about the same proportion between the sewaged and the unsewaged ground, while of green crops without sewage there were simply none. The following preliminary analyses of the sewage of Romford as it enters on the farm, and of the same when diluted with a certain portion of effluent water as it goes over the land, and of the effluent water as it runs out of the drains, have been made for the Committee by Dr. Russell. From these it will be seen that the percentage of ammonia in the sewage is low, and that it is poor as compared with that of most other towns; that is to say, the sewage is highly diluted, a condition which many people believe to be the most difficult to deal with by irrigation. Nevertheless the analyses of the effluent water show in every case that the ammonia almost entirely disappears; and if we take into account the difference in volume between the effluent water and the sewage, we may regard the ammonia as practically non-existent in the former. On the other hand, it will be seen that there is a rather high percentage of nitrogen in the form of nitrates and nitrites. The origin of the bulk of this, it is only reasonable to presume, is ammonia in the sewage; but it is so far very satisfactory to find that the effect of irrigation, or, in other words, of "intermittent downward filtration," should be such a complete transformation of the ammonia. But still, even taking into account the greatly diminished volume of the effluent water as compared with the original sewage (see Table, p. 72), there is no doubt a considerable waste of fertilizing matter escaping in the effluent water. How far this is to be attributed to the newly formed drains not being yet consolidated, time alone can show.

Soil from Plot Q, Breton's Farm, not been sewaged. Specimen taken 15th July, 1870.

Soil exposed to air of a warm summer:—	per cent.
Stones too large to pass through holes of a sieve 3·88 millims. diameter	31·65
Soil passing through sieve	66·43
Roots, seeds, straw, &c. picked out of soil	·03
Moisture lost at 100° C.	1·89

Many of the stones of large size, weighing about 10 grammes.

Composition of the 66·43 per cent. of soil:—

	per cent.		per cent.
Amount insoluble in strong hydrochloric acid	60·70	Silica	trace
Ferric oxide	1·56	Sulphuric acid (SO_3)	0·03
Alumina	1·04	Phosphoric acid (P_2O_5)....	0·01
Lime	0·42	Carbonic acid (CO_2)	0·19
Magnesia	0·04	Chlorine .... about	0·003
Potash and soda	0·10	Nitric acid	a trace
Potash 0·07, soda 0·03		Loss on ignition..........	1·69

The carbonate of lime is not uniformly distributed throughout the soil, but apparently almost the whole of it exists as small white pieces, and can easily be picked out. Three determinations of the carbonic acid in the soil gave 0·155, 0·258, and 0·433 per cent. of CO_2.

A small portion of the iron exists as the ferrous salt.

The air-dried soil (without the stones) is capable of holding when saturated 34·6 per cent. of water.

Analyses of Sewage and Effluent Water—in 100,000 parts.

	Date, 1870.	Solid matter in solution dried at 100° C.	Suspended matter.	Chlorine.	Ammonia.	Albumenoid ammonia.	Nitrogen as nitrates and nitrites.
	July						
Sewage from town, daytime	20	109·20	54·70	11·18	5·266	0·376	0·000 [a]
" " nighttime.........	20, 21	60·20	15·80	8·80	1·164	0·060	0·000 [a]
" pumped on to land	20	95·80	30·60	9·85	4·629	0·204	0·000 [a]
	July						
Effluent water, pipe A	20	70·60	Small amount	6·85	0·003	0·037	1·718 [b]
" " pipe B	20	69·90		7·77	0·041	0·035	1·663 [b]
" " pipe C	20	92·80	1·30	9·66	0·046	0·036	2·301 [b]
	Aug.						
Sewage from town, temp. 66° F.......	15	84·30	54·70	14·63	4·270	0·260	0·000 [c]
" " temp. 64°.........	17	49·10	13·60	8·09	0·744	0·040	0·000 [d]
" pumped on to land, temp. 64°.	15	65·30	22·50	11·36	3·054	0·140	0·000 [e]
	Aug.						
Effluent water, pipe A, temp. 58° ...	15	69·00	......	7·46	trace	0·031	1·633 [f]
" " pipe B, temp. 62° ...	15	73·50	......	8·80	0·031	0·056	1·490 [g]
" " pipe C, temp. 62° ...	15	87·50	......	9·87	0·000	0·043	2·081 [h]

Total hardness of effluent water	....		51·350
Temporary ditto.	....	33·610	
Permanent ditto.	....	17·740	
			51·350

[a] Samples taken every two hours from 10 A.M. to 6 P.M. Average flow 256 gallons per minute. ——[b] Samples taken every two hours, from 10 A.M. to 6 P.M. Average flow 20 gallons per minute from each of the pipes A, B, C.——[c] Average flow 250 gallons per minute. One-eighth of this sample was taken at eight times in the day.——[d] Average flow 200 gallons per minute. One-third of this sample was taken at three times in the day.——[e] Average flow 680 gallons per minute. One-eighth of this sample was taken at eight times in the day. ——[f] Average flow 20 gallons per minute. One-sixth of this sample was taken at six times in the day.——[g] Average flow 25 gallons per minute. One-sixth of this sample was taken at six times in the day.——[h] Average flow 26 gallons per minute. One-sixth of this sample was taken at six times in the day.

Breton's Sewage Farm.—Statement of Average daily quantity of Sewage pumped on to Land, and of Effluent Water received therefrom.

Weekly return.	Date (inclusive) 1870.	Average tempe-rature.	Rainfall during week.	Average daily quantity of sewage delivered to the tank from town.	Average tempe-rature thereof.	Average daily quantity of effluent water returned.	Average tempe-rature thereof.	Average daily quantity of sewage distributed over land.	Average tempe-rature thereof.	Proportion of effluent water to sewage distributed.
No.		° F.	in.	galls.	° F.	galls.	° F.	galls.	° F.	
1.	June 12 to June 18	...	...	231,400	63	109,871	55	343,886	55	·319
2.	June 19 to June 25...	...	...	225,343	62	93,543	56	324,143	63	·289
3.	June 26 to July 2 ...	...	...	228,714	63	87,157	57	317,600	60	·274
4.	July 3 to July 9 ...	...	...	219,900	...	106,800	...	326,357	...	·327 [a]
5.	July 10 to July 16...	73	0·29	239,386	65	108,643	59	334,457	66	·325 [b]
6.	July 17 to July 23...	76	0·00	235,800	65	101,914	60	313,114	67	·326 [c]
7.	July 24 to July 30...	70	0·81	279,270	66	104,343	61	352,929	66	·296 [d]
8.	July 31 to Aug. 6 ...	71	0·71	365,000	67	133,714	64	379,471	67	·353 [e]
9.	Aug. 7 to Aug. 13...	70	0·29	265,214	66	128,857	61	303,371	67	·423 [f]
10.	Aug. 14 to Aug. 20...	68	0·02	280,000	66	109,371	61	314,857	65	·347 [g]
11.	Aug. 21 to Aug. 27...	64	0·50	287,750	64	109,671	58	342,086	64	·321 [h]
12.	Aug. 28 to Sept. 3 ...	62	0·51	321,328	63	104,506	58	360,800	63	·289 [i]
13.	Sept. 4 to Sept. 10...	63	1·15	334,357	62	118,800	58	360,500	62	·329 [j]

[a] Tank overflowed July 9, 2250 gallons.
[b] Effluent water turned into river July 16, 17,200 gallons.
[c] Effluent water turned into river July 21 and 23, 160,300 gallons.
[d] July 26, storm tank overflowed, 170,000 gallons; on 27th, 13,500 gallons: portion of effluent water run into river during week 84,100 gallons.
[e] August 1, storm tank overflowed, 300,000 gallons; portion of effluent water run into river, 512,700 gallons.
[f] Portion of effluent water turned into river during week, 622,500 gallons.
[g] Portion of effluent water turned into river during week, 501,300 gallons.
[h] Portion of effluent water turned into river August 21 and 23 to 27, 504,300 gallons.
[i] Portion of effluent water turned into river every day, 418,340 gallons.
[j] Portion of effluent water run into river every day, 624,100 gallons.

D.—*Experiments on the Air in Sewers and Drains. By* Dr. W. J. Russell, *Sept.* 5, 1870.

On the 16th of August I visited the sewer in Cambridge Place, Paddington, and I passed from it into the large sewer in Praed Street. The atmosphere in both was warm and damp, but there was very little smell. As the only direct entrance into the sewers is by the ventilating-holes in the streets, to obtain the air of the sewer for examination some lengths of glass tubing were fastened together and lowered into the sewer in Cambridge Place at the opening nearest to St. Mary's Hospital, so that the end was about 2 feet above the water in the sewer. A pair of bellows was used for pumping up the air, each open-

ing of the bellows drawing in about 50 cubic inches of air. A quantity of this air was passed through plugs of clean cotton-wool which had been heated from 110° to 120° C., and these were sent to Mr. Cooke for examination. One specimen of the wool, through which about 5000 cubic inches of the sewer air had been transmitted, was put into distilled water with a little white sugar to see if any germs similar to those lately described by Professor Heisch would become visible. The liquid was examined in a week's time, but none of the germs found. The experiments were made about 11 o'clock A.M.

The next experiment was made on the same day, about 2 hours later, on the air in the Ranelagh sewer, the largest in the Paddington district. The air was taken from an opening in Gloucester Terrace, and was drawn out by means of an air-pump. Some of the air was passed through cotton-wool, and some collected for analysis gave the following results :—

	cub. centims.
Volume of gas taken	14·86
Volume after absorption of carbonic acid	14·80
Volume after absorption of oxygen	11·71
	per cent.
Carbonic acid	0·40
Oxygen	20·79
Nitrogen	78·81
	100·00

The air was also allowed to pass over acetate-of-lead paper for 5 minutes, but no blackening took place.

Another experiment was made at the drain in the back kitchen of 34 Upper Hamilton Terrace, St. John's Wood. The bell-trap was taken up and a glass tube was put down the drain. The air was blowing up the drain at the time, and had a disagreeable smell. A specimen of this air gave the following results; it will be seen that it was quite free from any combustible gases :—

	vols.
Volume of air taken	229·65
After addition of explosive gas	346·43
After explosion	229·65
After absorption of carbonic acid	229·37
After addition of hydrogen	348·44
After explosion	204·40
	per cent.
Combustible gases	0·00
Carbonic acid	0·12
Oxygen	20·91
Nitrogen	78·97
	100·00

The following experiments were made on the air in a drain from a sink in a room in St. Mary's Hospital. This drain was selected as being the nearest to the main drain passing from the hospital into the Cambridge Place sewer. The bell-trap of this drain was taken up; a glass tube passing about a foot down it was firmly corked into it, and by means of the air-pump the air drawn out of it. First, a specimen of the air was passed through cotton-wool, one specimen sent to Mr. Cooke, another treated with distilled water and sugar; the result of this experiment, as in the former case, was

negative. A specimen of the air from this drain was also analyzed, and gave the following results:—

	cub. centims.
Volume of air taken	11·69
After absorption of carbonic acid	11·63
After absorption of oxygen	9·21
	per cent.
Carbonic acid	0·51
Oxygen	20·70
Nitrogen	78·79
	100·00

A large quantity of this air was now drawn through water, and the water tested for ammonia and albumenoid ammonia. The experiment was made as follows:—a measured quantity of water (in this case four gallons) was allowed to run out of a gas-holder; the air thus drawn out of the drain first passed over acetate-of-lead paper, then through three small flasks, each containing 80 cub. centims. of pure distilled water; the tubes passing into the water were surrounded with platinum gauze, so as to break up the bubbles in the water. The experiment lasted $3\frac{1}{4}$ hours. The 240 cub. centims. of water in the flasks was put into a retort and distilled with a little carbonate of soda; it gave a trace of ammonia, about $\frac{1}{100}$ of a milligramme.

These experiments must be looked upon as simply tentative, but certainly indicate a purer air in these sewers than might have been anticipated.

Report by Mr. M. C. Cooke, M.A., *Aug.* 27, 1870.

I have examined microscopically the contents of the tubes sent to me, viz.—

No. 1. Air from Cambridge Place sewer, about 5000 cubic inches of which passed through the cotton-wool.

No. 2. Air from the same sewer, of which about 7000 cubic inches passed through the cotton-wool.

No. 4. Air from large sewer in Gloucester Place, about 2950 cubic inches of which passed through the wool.

No. 5. Air from sink-drain in Hospital, about 2950 cubic inches of which passed through the wool.

These were all examined separately and without any contact. All utensils, slips of glass, &c. were quite clean.

The method adopted in all instances was uniform.

The plug of cotton-wool was immersed in distilled water (freshly distilled) and well shaken in the water in a clean tube. The water with the organisms in suspension was then examined, drop by drop, till nearly exhausted. Whether this was the best method to adopt I am not certain, but the process was the same for the four samples.

The results generally indicate comparative freedom from organic bodies; in Nos. 4 and 5 perhaps an insufficient quantity of air was passed through the wool, as compared with Nos. 1 and 2.

No. 5 contained a very few starch-granules (Pl. III. fig. 17), a little granular matter, and two or three brownish spores, almost identical with fungi-spores of the genus *Macrosporium*. They are club-shaped, $\cdot 0015 \times \cdot 0005$ inch in size, with three or four septa; the upper portion coloured, the lower or narrower portion (the base) colourless. Species of this genus are common on

BRITISH ASSOCIATION. COMMITTEE ON THE TRE

TABULATION COMPILED FROM RETURNS FURNISHED BY 200 TOWNS

Registration Division	County.	No. of towns in consecutive order	Name of Town and District.	Watershed.	Character of Authority existing for Sanitary Purposes	Population: Of the whole district.	Population: Of the portion sewered.	Water Supply: Source, public or private, or both.	Water Supply: Daily average supply per head.	Water Supply: Total average daily supply delivered.	Number of Receptacles of Excretal Matter: Of water closets.	Of earth-closets.	Of privies.	How refuse is removed; whether by a system of underground sewers, public scavenging, or both, or otherwise: Excretal matter.	House slops and other liquid refuse.	Ashes, street sweepings, and other solid refuse.
1	2	3	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
	Surrey	1	EPSOM	Thames	Local Board	5,000	4,000	Both	galls. 27	galls. 135,000	750	None	Few or none	By sewers	By sewers	By scavenging
		2	GUILDFORD	"	Local Board	9,500	......	Both	30	......	Very few	2 or 3	......	By scavenging by occupiers	To cesspits	By scavenging (public)
		3	KINGSTON	"	Corporation	12,000	12,000	Both	27	222,000	......	None	......	......	By sewers	By scavenging by occupier and corporation.
		4	REIGATE	"	Local Board	14,000	6,000	Both	......	......	......	......	......	By sewers and cesspools	By sewers and cesspools	By private scavenging
		5	RICHMOND	"	Vestry	12,000	12,000	Both	......	......	2,000	None	......	By sewers	By sewers	By scavenging
		6	SURBITON (St. Mark)	"	Local Board	7,200	7,100	Public	30	213,000	General	......	......	By sewers	By sewers	
	Kent ...	7	ASHFORD	Stour	Local Board	8,000	7,000	Both	20	200,000	......	......	......	By sewers	By sewers	
		8	BROMLEY	Thames	Local Board	10,000	800	Both	......	......	......	10	......	By scavenging by occupiers	By farmers from cesspools	By scavenging...
		9	CANTERBURY	Stour	Corporation as L. B.	22,000	20,000	Both	16	......	1,300	None	3,000	By sewers	By sewers	By scavenging
		10	DOVER	......	Corporation as L. B.	24,000	24,000	Both	50	1,038,740	4,197	None	100	By sewers	By sewers	By scavenging
SOUTH-EASTERN.		11.	HYTHE	......	Town Council	3,000	......	Both	......	......	General	None	......	By sewers	By sewers	By scavenging
		12.	MAIDSTONE	Medway	Local Board	23,000	15,000	Both	......	......	......	......	......	......	By sewers	By scavenging by board and occupiers.
		13.	RAMSGATE	......	Local Board	13,000	4,000	Both	14	56,000	......	None	......	By sewers and scavenging	By sewers and cesspools	......
		14.	TONBRIDGE	Medway	The Sewer Authority	8,890	8,890	Both	......	......	......	......	......	By sewers and private scavenging	By sewers	By scavenging by occupiers
		15.	TUNBRIDGE WELLS	"	24 Commissioners	16,000	13,000	Public	14½	188,500	General	......	......	By sewers	By sewers	
	Sussex	16.	BRIGHTON		Corporation as L. B.	[illegible]	56,000	Public	28	[illegible]	4,010	15	[illegible]	By sewers and private scavenging.	By sewers and cesspits in chalk.	By scavenging
		17.	HASTINGS	......	Local Board	25,000	25,000	Both	20	500,000	4,000	1	None	By sewers	By sewers	By scavenging
		18.	WEST HOVE	......	Improvement Commissioners.	5,000	4,900	Public	15	72,000	1,200	......	10	By sewers	By sewers	By scavenging...
	Hampshire	19.	ALTON	Thames	Local Board	4,000	3,400	Private wells	......	......	420	7	20	By sewers	By sewers	By scavenging
		20.	ANDOVER	Test and Itchen	Town Council	5,000	4,000	Private	......	......	......	7	......	By sewers and scavenging	By sewers	By scavenging......
		21.	FAREHAM	......	Local Board	6,200	4,600	Public	15	65,000	500	......	None	By sewers	By sewers	By scavenging...
		22.	NEWPORT	Medina	Local Board	8,000	7,000	Both	......	......	......	......	......	......	By sewers	By scavenging......
		23.	SOUTHAMPTON	......	Corporation as L. B.	50,000	50,000	Public	30	1,500,000	General	2	70	By sewers	By sewers	By scavenging
		24.	WINCHESTER	Itchen	Corporation as L. B.	17,000	None	Public	......	......	......	......	......	By private scavenging	......	By scavenging...
	Berkshire	25.	ABINGDON	Thames	Paving Commissioners	7,000	3,000	Private wells	......	......	353	None	......	By sewers and scavenging	By sewers	By scaven.
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.

[TRE]ATMENT AND UTILIZATION OF SEWAGE.

[TOWNS] SELECTED FOR CLASSIFICATION. SEPTEMBER 1870.

18	19	Storm- and Surface-Waters. How disposed of. 20.	Subsoil-Water; how disposed of. 21.	Mode of Ventilation. 22.	Discharge from Sewers, independent of Scavenging. Ordinary or dry weather daily quantity (exclusive of storm-water). Total. 23.	Per head of population. 24.	How disposed of. By simple discharge, unmitigated. 25.	By filtration before ultimate discharge. 26.	By chemical treatment before ultimate discharge. 27.	By irrigation. 28.	Return derived. Total per annum. 29.	Per head per annum. 30.	Scavenging (Public). How effected. 31.	Total annual cost. 32.	Annual amount received for refuse. 33.	Difference between cost and return. Profit. Total. 34.	Per head. 35.	Loss. Total. 36	Per head. 37	No. 38
				By manholes	gals. 145,000	gals. 36		Wholly, before irrigation.		Wholly	£	pence	By contractor	£ Nil	£ Nil	£ None	pence None	£ None	pence None	1
													By contractor							2
..	..1	By sewers	By sewers	By special pipes and flues.	400,000	33	Wholly						By contractor; street sweepings only.	110	Nil					3
		By sewers	By sewers				Wholly													4
		By sewers	By sewers	By special pipes			Wholly													5
		By sewers		By gratings			Wholly													6
		By sewers		None	150,000	21	Wholly													7
		By surface-drains					Wholly						By contractor; ashes &c. only.							8
		By old sewers	By sewers partly		1,152,000	58		Wholly					By contractor and local board.	450	125			325	3 5	9
	31	By old sewers, roof-water to new sewers	By sewers	By factory chimneys	3,438,740	143	Wholly						By contractor	310	Nil			310	3 1	10
							Wholly						By contractor	Nil	Nil	None	None	None	None	11
		[illegible]y sewers	By old sewers				Wholly						By contractor; street-sweepings only.	250	45			205		12.
	..	By sewers, roof-water col[illegible]					Wholly													13.
				By chimneys and gratings			Wholly													14
										Wholly										15
		By sewers		By gratings, special flues, &c.	1,800,000	32	Wholly													16
	28	By sewers	By sewers		600,000	24							By local board		600					17
	24	By sewers			72,000	15	Wholly						By commissioners	220	130			9[illegible]	4 3	18
1	36	By old sewers chiefly	By special drain	By shafts	126,000	37			Wholly				By local board	44	7			37	2 2	19
		By sewers	By sewers				Wholly, after precipitation													20
	33	By special drains chiefly, part by sewers.		By shafts and gratings	180,000	39		Wholly					By contractor	Nil	7	7	·3			21
..	31	By sewers	By sewers				Wholly						By contractor							22
..		By sewers	By sewers		1,500,000	30	Wholly		The ABC process, [illegible]				By contractor and local board	300						23
	..	By surface-drains											By contractor	245	Nil			245	3 5	24
400	24	By sewers and surface-drains.	By sewers				Wholly						By commissioners	187	16			171	5 9	25
18	19	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36	37.	38.

1	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	
S.E. cont'd	Berkshire (continued)	26.	READING	Thames	Local Board	30,000	...	Public	30	...	1,000	None	4,000	By surface-drains and scavenging	By surface-drains and scavenging	By scavenging		26	By old drains and surface-streams	...	...	...
		27.	WINDSOR	"	Local Board	10,000	9,500	Public	25	237,500	General			By sewers	By sewers			25	By sewers	...	By special shafts	
	Middlesex	28.	EALING	"	Local Board	8,000	8,000	Public	25	200,000	1,700	None	12	By sewers	By sewers	By scavenging, ashes only	1,250	25	Both by sewers and old drains.	By sewers	By manholes and ventilators.	37
		29.	ENFIELD	"	Local Board	14,000	4,700	Public	33	155,000	170		10	By sewers and scavenging	By sewers and surface-drains	By scavenging	12,653	30	By surface-streams	...	...	11
		30.	HORNSEY	"	Local Board	11,000	...	Both	...	...	...	None	...	By sewers and private scavenging.	By sewers and surface-drains	By scavenging by occupiers	2,700	26	By sewers and surface-streams			
		31.	TWICKENHAM	"	Local Board	10,000	6,000	Both	15	100,000	1,900	None	800	By sewers and from cesspools	By sewers and from cesspools.	By scavenging	150	21	By sewers and surface-streams.	By sewers	..	20
		32.	UXBRIDGE	"	Local Board	7,500	7,500	Public	15	112,500	1,600	None	50	By sewers	By sewers	By scavenging	...	...	By old sewers		By shafts	.
	Hertfordshire	33.	CHESHUNT	"	Local Board	7,500	5,000	Private		25,000		None		By sewers and private scavenging	By sewers and surface-drains	By private scavenging	7,500	25	By sewers and surface-streams			
		34.	HERTFORD	"	Corporation	6,800	6,400	Both	61½	...	433	14	5	By sewers	By sewers	By scavenging	90	25	By sewers	By sewers		
		35.	WALTHAM ABBEY	"	Local Board	5,000	3,300	Both	...	...	90	None	650	By sewers and private scavenging.	By sewers and on land	By private scavenging	150		By sewers			
SOUTH MIDLAND.	Buckinghamshire	36.	AYLESBURY	"	Local Board	6,250	6,250	Both	...	...	...	...	...	...	By sewers			25	By sewers			..
	Oxfordshire	37.	BANBURY	"	Local Board	10,300	...	Both	21	...	General	...	...	By sewers	By sewers	By scavenging			By sewers	...	By down spouts and shafts.	30
		38.	BICESTER	"	Local Board	2,700	...	Private	...	...	...	...	...	...	By sewers	...	...	...	By sewers	...	By shafts	
		39.	OXFORD	"	Local Board	33,000		Both	30		1,000	3	3,500	By sewers and private scavenging	By sewers and to cesspools	By scavenging	1,800	30	By sewers		None	
	Northamptonshire	40.	DAVENTRY	Nene	Corporation	4,100	3,800	Both	...	...	50	1	500	By sewers and private scavenging.	By sewers	By scavenging	40	...	By sewers, but part roof water used.	...		
		41.	NORTHAMPTON	"	Improvement Commissioners	40,000		Public	15			None		By sewers	By sewers	By scavenging			By sewers	By sewers	By manholes	60
		42.	PETERBOROUGH	"	Improvement Commissioners.	12,000	12,000	Private	...	...	...	...	...	By sewers and private scavenging.	By sewers	...	...	...	By sewers		By manholes	
		43.	WELLINGBOROUGH	"	Local Board	8,000	8,000	Both	17		900	20	100	By sewers and private scavenging.	By sewers	By scavenging	350	22	By sewers	By sewers	By down spouts	
	Huntingdonshire. Bedfordshire	44.	BEDFORD	Ouse	Local Board	16,500	...	Both	15	...	General	...	...	By sewers	By sewers	...	...	24	By old sewers	By sewers	By special pipes	70
		45.	LUTON	Thames	Local Board	18,000	18,000	Private					General	By sewers and public scavenging	By sewers				By sewers		..	.
	Cambridgeshire	46.	CAMBRIDGE	Ouse	Improvement Commissioners.	27,000	27,000	Both	19	...	General	None	...	By sewers	By sewers	By private scavenging (ashes only).	...	24	By sewers		By down spouts	1,00
		47.	ELY	"	Local Board	8,000	6,200	Public	30	190,000	1,000	2	5	By sewers	By sewers	By scavenging	400	22	By old sewers, except some of the roof-water, &c	By old sewers	...	.
		48.	WISBECH	Nene	Corporation as L. B.	9,300	None	Both			...	None	2,300	By scavenging	Carried to streams, canal, cesspools, &c	By scavenging	1,000	23	By surface-drains; roof-water retained for use	..	..	
	Essex	49.	BRAINTREE	Brane	Local Board	5,000	4,000	Public	20	80,000	General		20	By sewers	By sewers		.		Chiefly by old sewers	..		
		50.	CHELMSFORD	"	Local Board	9,000	8,500	Both	15	130,000	General	10	...	By sewers	By sewers	By scavenging	...	22	Chiefly by old sewers	By sewers	By shafts and down spouts.	30
		51.	COLCHESTER	Colne	Commissioners	25,000	20,000	Both				None		...	By sewers	By scavenging			By sewers		..	
		52.	EPPING	Thames	A special drainage district	2,000	None	Private	...	...	...	12	General	By surface-drains and scavenging	By surface-drains and thrown on land	By scavenging by occupiers			By surface drains	.		
		53.	HALSTEAD	Colne	Local Board	6,000	6,000	Both	15	78,000	200	None	[illegible]	By sewers and part of by private scavenging	By sewers	Private scavenging	800		By old sewers	By sewers	...	10
EASTERN	Suffolk	54.	BURY ST EDMUNDS	Ouse	Corporation	14,000	14,000	Both						By sewers and private scavenging	By sewers	By private scavenging			By sewers		By pipes and storm overflows	
		55.	IPSWICH	Orwell	Local Board	40,000	None	Both				4		By private scavenging	Collected from sewers, wells and cesspools	By private scavenging			By surface drains	.		
	Norfolk	56.	DISS	Waveney	Local Board	3,500	...	Private wells, &c.	...	...	...	...	General	By sewers and scavenging		...		22	...	..	...	
		57.	KINGS LYNN	...	Paving Commissioners	16,000	16,000	Public	56	890,000	...	None	General	By sewers and private scavenging	By sewers	By scavenging	...	...	By sewers	By sewers	By down spouts	
		58.	NORWICH	Yare	Local Board	80,000	70,000	Both	15	1,050,000	3,500	None	...	By sewers and scavenging	By sewers and to cesspools	By scavenging	800	22	By sewers	...	By down spouts and gratings.	
		59.	SWAFFHAM	Ouse	Local Board	4,000	...	Both	...	...	...	...	350	By public and private scavenging.	By sewers and surface-drains	By scavenging	...	...	By sewers and surface drains.	...	...	
		60.	YARMOUTH	...	Corporation as L. B.	33,000	33,000	Both	...	...	3,000	None	5,000	By sewers and scavenging	By sewers	By scavenging	1,000	31	By sewers		...	
1	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	

* Including ashes.

† Including the sewage deposit.

23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.
		...	...	...	...	...	...	...	...	...	...	...		...	26
														...	27
	44	...	Wholly after deodorization	Wholly before filtration.	...	60*	1·8	By contractor (the house-refuse only)	...	60†	...	...	...	...	28
		Wholly...	...	...	...	...	...	...	...	...	...	...	...	...	29.
		Wholly...	...	...	...	...	...	...	...	...	...	...	...	...	30.
		[illegible]		...	...	...	...	By contractor (ashes only) and board	250	Nil	...	...	250	6·	31
			Wholly	...	...	...	...	By board ...	150	30	...	...	120	3·8	32
		[illegible]			...	...	...	...	...	...	...	...	...	...	33
			Wholly after deodorization	Wholly before filtration.	...	...	...	...	...	...	...	...	...	...	34
		[illegible]												...	35.
		[illegible]			...	...	...	...	...	...	...	...	...	...	36
			Wholly before irrigation		Wholly after filtration	...	...	...	...	...	...	...	...	...	37
					Wholly ...	...	...	...	...	...	...	...	...	...	38
		Wholly...	...	...	...	...	...	By board ...	1,100	120	...	...	980	7·1	39
		[illegible]	...	...	...	...	...	By contractor ...	30	Nil	...	...	30	1·8	40
			...	Wholly...	...	...	...	By commissioners ...	1,000	560†	...	...	440	2·6	41
...		[illegible]...	...	...	...	...	...	...	...	...	...	...	...	...	42
			Wholly...	...	...	...	...	...	...	...	...	...	...	...	43.
			...	...	Wholly...	...	...	...	...	...	...	...	...	...	44
			Wholly after deodorization.	Wholly before filtration.	...	...	...	By board ...	...	...	...	...	...	...	45
[illegible]	[illegible]	[illegible]	...	...	...	...	...	By commissioners (street sweepings only).	1,200	200	...	...	1,000	8·9	46.
		...	Wholly...	...	...	...	...	By board ...	84	42†	...	...	42	1·3	47.
			...	...	...	...	...	By board ...	189	Nil	...	...	189	4·9	48.
		Partially ...	...	...	Partially ...	...	...	...	...	...	...	...	...	...	49
		Partially ...	...	...	Partially ...	...	...	By board ...	...	...	...	...	...	...	50
		Wholly...	...	...	...	...	...	By commissioners, but occupiers pay cost.	...	...	...	...	...	...	51
		...	...	...	...	...	...	...	...	...	...	...	...	...	52.
		[illegible]						...	...	...	...	...	...	...	53
				...	Wholly ...	...	...	...	...	...	...	...	...	...	54
															55
		Wholly...	...	...	...	...	...	...			...	...	...	...	56
		Wholly...	...	...	...	...	...	By commissioners ...	...	...	...	...	...	...	57
		[illegible]						By contractor ...	400	Nil	...	...	400	1·2	58
		[illegible]	...	...	...	...	...	By contractor ...	13	Nil	...	...	13	·8	59
		[illegible]	...	...	...	...	...	By contractor ...	200	Nil	...	...	200	1·5	60
23	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.

1.	21.	31.	32.	33.	34.	35.	36.	37.	38.
SOUTH-WESTERN.									
al	sewers	ard	630*	20	....	....	610	11·3	61.
....	....	ntractor	40	Nil	....	....	40	1·2	62.
al	N........	ntractor	530	Nil	....	....	530	2·5	63.
)	N........	ard	1,000	600	....	....	400	2·8	64.
)	sewers	....	....	....	....	....	....	....	65.
)	sewers	rd and contractor	1,860	Nil	....	....	1,860	6·4	66.
)	N........	ard	99	27	....	....	72	5·1	67.
al	sewers	ard	1,000	150	....	....	850	10·2	68.
)	....	ntractor	195	Nil	....	....	195	3·9	69.
)	N........	ntractor	28	Nil	....	....	28	1·5	70.
al	N........	ard	596	390	....	....	206	5·2	71.
....	....	ntractor	1,500	Nil	....	....	1,500	6·5	72.
....	....	ard	Nil	Nil	None	None	None	None	73.
....	N........	....	....	....	....	....	....	....	74.
al	N........	ntractors	303	Nil	....	....	303	4·8	75.
....	N........	ntractor	45	Nil	....	....	45	2·3	76.
al	sewers	ntractor	....	....	....	....	....	....	77.
....	sewers	mmissioners	....	....	....	....	....	....	78.
....	....	....	....	....	....	....	....	....	79.
WEST MIDLAND.									
)	sewers	ntractor	422	100	....	....	322	4·5	80.
5	N........	....	143	....	....	....	143	4·6	81.
)	sewers	....	....	100	....	....	....	....	82.
....	sewers	ard (street-sweep- s only).	....	....	....	....	....	....	83.
)	sewers	ard	280	38	....	....	242	10·2	84.
....	....	....	....	....	....	....	....	....	85.
....	....	ard	1,700	250	....	....	1,450	15·1	86.
)	sewers (pa	....	....	....	....	....	....	....	87.
)	....	oard, streets; by tract, ashes &c.	1,150	....	....	....	....	....	88.
)	N........	ard	182	10	....	....	172	4·1	89.
)	....	....	....	....	....	....	....	....	90.
)	....	ard (street-sweep- s only).	....	40	....	....	....	....	91.
5	sewers	oard	612	205	....	....	407	5·1	92.
....	....	....	....	....	....	....	....	....	93.
)	sewers (pa	....	....	....	....	....	....	....	94.
....	....	....	274	....	....	....	274	1·3	95.
1.	21.	31.	32.	33.	34.	35.	36.	37.	38.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
SOUTH-WESTERN	Wiltshire	61.	SALISBURY	Avon	Corporation as L. B.	13,000	13,000	Public	45	585,000	General	None	
	Dorsetshire	62.	BRIDPORT	Brit	Corporation as L. B.	8,000		Private					
	Devonshire	63.	DEVONPORT		Corporation as L. B.	50,000	49,000	Both	30		General	None	35
		64.	EXETER	Exe	Corporation as L. B.	35,000	35,000	Both	24	857,000	6,000	None	None
		65.	NORTHAM	Torridge	Local Board	4,000	3,000	Both			100	None	
		66.	PLYMOUTH		Local Board	70,000	69,000	Public	50	3,250,000	[illegible]	None	None
		67.	SIDMOUTH		Local Board	3,400	2,500	Both	22		1,000	None	20
		68.	TORQUAY		Local Board	[illegible]	[illegible]	Both	30	610,000	General	2	12
		69.	WEYMOUTH		Corporation as L. B.	12,000	11,000	Public			1,000	40	400
	Cornwall	70.	BODMIN	Camel	Town Council	[illegible]	4,000	Both	20		100	None	600
		71.	PENZANCE		Corporation as L. B.	9,500	9,500	Public	25	250,000	General	None	None
	Somersetshire	72.	BATH	Avon	Local Board	55,000	52,000	Public	14	641,640		50	
		73.	FROME	,,	Local Board	10,000	10,000	Private				10	
		74.	ILMINSTER	Parret	The Vestry	2,000	2,000	Both				None	
		75.	TAUNTON	,,	Local Board	15,000	15,000	Both		300,000	General	None	
		76.	WELLS	Brue	Corporation as L. B.	4,700	4,700	Private				None	
	Gloucestershire	77.	BRISTOL	Avon	Corporation as L. B.	171,000	171,000	Public			General	None	None
		78.	CHELTENHAM	Severn	Improvement Commissioners.	43,000	40,000	Both					
		79.	CIRENCESTER	Thames	Board of Guardians	21,000	None	Private					General
		80.	GLOUCESTER	Severn	Corporation as L. B.	17,000	[illegible]	Both	25	420,000	2,600	None	30
		81.	[illegible]	,,	Local Board	7,500	6,500	Both	7	45,000	216	None	
WEST MIDLAND	Herefordshire	82.	HEREFORD	Wye	Corporation	18,000	16,000	Public	[illegible]	[illegible]	[illegible]	2	
		83.	LEOMINSTER	,,	Corporation as L. B.	5,100	4,500	Both	10	60,000			
	Shropshire	84.	BRIDGNORTH	Severn	Corporation as L. B.	5,700	5,700	Public	36	216,000	[illegible]	None	
		85.	SHIFNAL	,,	Board of Guardians	[illegible]	[illegible]	Private					
		86.	SHREWSBURY	,,	Corporation as L. B.	23,000	None	Both	20			1	4,000
	Staffordshire	87.	BURSLEM	Trent	Local Board	[illegible]	[illegible]	Public	20	500,000	[illegible]	None	2,000
		88.	BURTON-ON-TRENT	,,	Local Board	20,000	20,000	Both			60	20	2,000
		89.	FENTON	,,	Local Board	10,000	3,000	Public	10	30,000	60	None	2,000
		90.	HANLEY	,,	Corporation as L. B.	45,000		Public	20		300		8,500
		91.	LICHFIELD	,,	Corporation	6,000	5,000	Both			240		
		92.	LONGTON	,,	Corporation as L. B.	19,000	3,000	Public	15	45,000	25	2	4,000
		93.	STAFFORD	,,	Improvement Commissioners	16,000	None	Private					
		94.	TUNSTALL	,,	Local Board	[illegible]	10,000	Both	20	200,000	[illegible]	None	2,000
		95.	WALSALL	,,	Local Board	50,000	40,000	Public					General

3.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.
61.	By sewers	By sewers	By scavenging			By sewers	By sewers				Wholly			
62.	By sewers and scavenging	By sewers	By scavenging			By old sewers					Wholly			
63.	By sewers	By sewers	By scavenging	769	35	By sewers					Wholly			
64.	By sewers	By sewers	By scavenging	[illegible]	34	By sewers		None			Wholly			
65.	By sewers and scavenging	By sewers		4,190		By sewers	By sewers				Wholly			
66.	By sewers	By sewers	By scavenging	1,400	26	By sewers	By sewers	By high shafts	[illegible]	43	Wholly			
67.	By sewers	By sewers	By scavenging	650	29	By sewers					Wholly			
68.	By sewers	By sewers	By scavenging	[illegible]	35	By sewers	By sewers	By shafts	[illegible]	[illegible]	Wholly			
69.	By sewers	By sewers	By scavenging	500	18	By sewers					Wholly			
70.	By sewers and scavenging	By sewers	By scavenging	[illegible]	[illegible]	By surface-drains and collected for use.					Wholly			
71.	By sewers	By sewers	By scavenging	400	40	By sewers					Wholly			
72.	By sewers	By sewers	By scavenging	299,000	26	By sewers		By shafts	800,000	15	Wholly			
73.	By sewers and public scavenging.	Sold to cloth manufacturers	By scavenging			By sewers					Wholly			
74.	By sewers and private scavenging.	By sewers				By old sewers		By gratings			Wholly			
75.	By sewers	By sewers	By scavenging	8,000	26	By sewers					Wholly			
76.		By sewers	By scavenging			By sewers					Wholly			
77.	By sewers	By sewers	By scavenging			By sewers	By sewers				Wholly			
78.		By sewers	By scavenging	1,400	28	By sewers and surface-streams.	By sewers		1,046,000	26		Wholly		
79.	By scavenging		By scavenging			By surface-drains								
80.	By sewers	By sewers	By scavenging	[illegible]	27	By sewers	By sewers		[illegible]	36	Wholly			
81.		By sewers	By scavenging	110		By sewers			100,000	15			Wholly	
82.		By sewers	By scavenging	[illegible]	22	By sewers	By sewers	By shafts	900,000	50	Wholly			
83.	By sewers and private scavenging	By sewers	By scavenging (private for ashes, public for streets)	200	27	By sewers	By sewers				Wholly			
84.		By sewers	By scavenging	1,100	30	By sewers	By sewers				Wholly			
85.	By sewers and private scavenging	By sewers	By private scavenging	[illegible]	26	By sewers		By gratings			Wholly			
86.	By private scavenging	By drains and surface-streams	By scavenging			By drains and surface-streams								
87.	By sewers and private scavenging.	By sewers	By private scavenging	1,000		By sewers	By sewers partly				Partially			Partially
88.	By sewers and public scavenging	By sewers	By scavenging		24	By sewers		None	3,500,000	175	Wholly after precipitation			
89.	By sewers and public scavenging	By sewers and surface-streams	By scavenging	500		By surface-streams					Wholly			
90.			By private scavenging	2,000	27	By surface-streams								
91.		By sewers				By sewers			32,000	6	Wholly			
92.	By sewers and public scavenging.	By sewers and surface-streams	By scavenging	900		By sewers	By sewers				Wholly			
93.	By private scavenging	By surface-streams												
94.	By sewers and private scavenging.	By sewers and surface-streams	By scavenging	250		By sewers	By sewers (partly)				Wholly			
95.	By sewers and private scavenging.	By sewers	By private scavenging			By sewers		None						

3.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.
61.			By board	630*	20			610	11·3	61.
62.			By contractor	40	Nil			40	1·2	62.
63.			By contractor	530	Nil			530	2·5	63.
64.			By board	1,000	[illegible]			100	2·8	64.
65.										65.
66.			By board and contractor	1,860	Nil			1,860	6·4	66.
67.			By board	99	27			72	5·1	67.
68.			By board	[illegible]	[illegible]			[illegible]	10·2	68.
69.			By contractor	195	Nil			195	3·9	69.
70.			By contractor	28	Nil			28	1·5	70.
71.			By board	596	390			206	5·2	71.
72.			By contractor	1,500	Nil			1,500	6·5	72.
73.			By board	Nil	Nil	None	None	None	None	73.
74.										74.
75.			By contractors	303	Nil			303	4·8	75.
76.			By contractor	45	Nil			45	2·3	76.
77.			By contractor							77.
78.			By commissioners							78.
79.										79.
80.			By contractor	422	100			322	4·5	80.
81.				143				143	4·6	81.
82.					100					82.
83.			By board (street-sweepings only).							83.
84.			By board	280	38			242	10·2	84.
85.										85.
86.			By board	1,760	250			1,150	15·1	86.
87.										87.
88.			By board, streets; by contract, ashes &c.	1,150						88.
89.			By board	182	10			172	4·1	89.
90.										90.
91.			By board (street-sweepings only).		40					91.
92.			By board	612	205			407	5·1	92.
93.										93.
94.										94.
95.				274				274	1·3	95.

* Including cost of watering, &c.

14.		23.	24.	2	32.	33.	34.	35.	36.	37.	38.
......	.....	50,000	10	....	450	....	....	....	450	18·0	96.
......	.....	....	......	Wholl	....	....	....	....	....	....	97.
Gen	gs...	....	......	Partia preci	11,500	5,500	....	....	6,000	4·0	98.
1,5	.....	....	......	....	575	....	....	....	....	....	99.
......	.....	1,000,000	50	....	....	....	....	....	....	....	100.
......	.....	300,000	34	....	....	....	....	....	....	....	101.
4	.....	500,000	50	....	....	....	....	....	....	....	102.
......	.....	3,000,000	34	....	....	....	....	....	....	....	103.
......	.....	....	......	Wholl	474	167	....	....	307	5·1	104.
8	.....	160,000	21	Wholl	....	....	....	....	....	....	105.
......	.....	....	......	Wholl the	853	....	....	....	853	8·2	106.
1,8	.....	....	......	Wholl	....	....	....	....	....	....	107.
2	.....	....	......	Wholl	....	....	....	....	....	....	108.
4	.....	....	......	Wholl	100	20	....	....	80	2·7	109.
Gen	.....	....	......	No sy	....	....	....	....	....	....	110.
8,0	.....	4,000,000	30	Wholl	6,100	4,050	....	....	2,050	3·6	111.
1,6	.....	637,800	53	Wholl	....	....	....	....	....	....	112.
8,0	.....	1,250,000	......	Wholl	2,728	633	....	....	2,095	10·1	113.
1,2	.....	....	......	Wholl	....	....	....	....	....	....	114.
......	.....	....	......	Wholl	....	....	....	....	....	....	115.
2,1	.....	300,000	30	Wholl	....	....	....	....	....	....	116.
2,0	.....	800,000	50	Wholl preci	300	Nil	....	....	300	4·5	117.
2,0	.....	....	......	Wholl	....	....	....	....	....	....	118.
2,2	.....	....	......	Wholl	....	....	....	....	....	....	119.
2,0	.....	....	......	Wholl	400	Nil	....	....	400	6·4	120.
1,1	.....	....	......	Wholl	400	Nil	....	....	400	7·1	121.
Gen	.....	....	......	....	....	....	....	....	350	3·4	122.
6,2	.....	....	......	Wholl	1,646	95	....	....	1,550	9·5	123.
1,2	.....	....	......	Wholl	70	Nil	....	....	70	2·4	124.
6	.....	108,000	8	....	400	Nil	....	....	400	5·5	125.
13,5	.....	2,000,000	29	....	3,100	480	....	....	2,620	7·8	126.
8	.....	1,000,000	154	Wholl	100	Nil	....	....	100	3·4	127.
6,6	wn	1,725,780	35	Wholl	3,172	1,568	....	....	1,604	4·8	128.
3,6	wn	....	......	Wholl	....	....	....	....	....	....	129.
3,[illegible]	.....	....	......	Wholl	700	100	....	....	600	4·8	130.
1		23.	24.		32.	33.	34.	35.	36.	37.	38.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
WEST MIDLAND (cont.)	Worcestershire		MALVERN	SEVERN	Local Board	6,000	5,500	Both	6	50,000	1,000	None		By sewers	By sewers	By scavenging	1,500	30	By sewers	By sewers	None	50,000	10	...			Wholly			By contractor	450				450	1 0	96
		97.	WORCESTER	"	Local Board	35,000	31,000	Public	25	850,000	General			By sewers	By sewers				By sewers		By shafts			Wholly													97
	Warwickshire		BIRMINGHAM	TRENT	Corporation	3[illegible]		Both					General	By sewers and public scavenging	By sewers	By scavenging			By sewers	By sewers	By shafts and gratings			Partially, after precipitation			Partially, after precipitation		...	By board	11,5[illegible]0	5,500			6,000	4 0	98
			COVENTRY	SEVERN	Local Board	41,000	41,000	Both	17		3,8[illegible]0	20	1,500	By sewers and scavenging	By sewers	By scavenging (private for ashes, public for streets)	2,000	28	By sewers		By down spouts				Wholly			...		By board (street sweepings only)	575	..					99
			LEAMINGTON	"	Local Board	20,000	20,000	Public	20	100,000	General			By sewers	By sewers			25	By separate sewers		By gratings	1,000,000	50			Wholly by ABC process	Intended										100
			RUGBY	"	Local Board	9,000	8,700	Both	23	190,000	1,400	None		By sewers	By sewers	By scavenging (private for ashes, public for streets)	110	23	By sewers		By chambers	300,000	34				Wholly			By board (street-sweepings only)							101
			WARWICK	"	Corporation as L. B	11,000	10,000	Both	30	300,000	2,000	None	400	By sewers and scavenging	By sewers	By scavenging (private for ashes, public for streets)	600	26	By sewers		By down spouts	5[illegible]0,000	50	...			Wholly										102
NORTH MIDLAND	Leicestershire		LEICESTER	TRENT	Local Board	9[illegible],000	6[illegible],000	Both		1,780,000			...	By sewers	By sewers				By old sewers	By sewers	By special pipes	3,000,000	34			Wholly											103
	Rutlandshire. Lincolnshire		BOSTON	WITHAM	Local Board	14,000	14,000	Public	25	300,000		6		By sewers and private scavenging	By sewers	By scavenging		22	By sewers		By shafts			Wholly						By board	474	167	...		307	5 1	104
			GAINSBOROUGH	TRENT	Local Board	7,500	7,500	Both		80,000	800	None	800		By sewers	By scavenging	200	32	By old sewers	By sewers		160,000	21	Wholly						By contractor			...				105
		106.	LINCOLN	WITHAM	Local Board	25,000		Both	13			4		By public scavenging	By surface-streams	By public scavenging			By drains and surface-streams					Wholly (from the drains).						By contractors	853	...			853	8 2	106
		107.	LOUTH	LUDD	Town Council	11,000		Both			254	8	1,823	By sewers and private scavenging.	By sewers	By scavenging (private for ashes, public for streets).	178	31	By sewers (partly)					Wholly						By contractor (streets only).							107
		108.	SLEAFORD	WITHAM	Local Board	3,800	3,800	Private			60	2	250	By sewers and private scavenging	By sewers	By private scavenging			By sewers	By sewers				Wholly													108
			SPALDING	WELLAND	Improvement Commissioners	7,000	5,500	Both	27		125	3	[illegible]		By sewers and [illegible] wells	By scavenging	210		By old sewers (roof-water collected for use)					Wholly						..	1[illegible]	[illegible]			81	2 7	109
			STAMFORD	"	Corporation	8,000	None	Both				12	General	...	[illegible] in cesspools	By scavenging			By surface drains					No system						..							110
	Nottinghamshire		NOTTINGHAM	TRENT	Corporation as L. B	13[illegible],000	1[illegible],000	Both	30	3,500,000	2,[illegible]0	10[illegible]	8,000	By sewers and public scavenging.	By sewers	By scavenging	1,870	25	By sewers	By sewers	By manholes	4,000,000	30	Wholly				..		By board	61[illegible]	4,05[illegible]	..		2,[illegible]0	3 6	111
	Derbyshire		CHESTERFIELD	OUSE	Local Board	12,000	12,000	Public	20	240,000	170	None	1,636		By sewers	By scavenging	1,400	28	By sewers	By sewers		637,800	53	Wholly													112
			DERBY	TRENT	Corporation as L. B.	50,000		Both	25				8,000	By sewers and public scavenging.	By sewers	By scavenging	2,000	26	By sewers			1,250,000		Wholly						By board	2,728	633			2,096	10 1	113
NORTH WESTERN	Cheshire		ALTRINCHAM	MERSEY	Local Board	9,000	9,000	Public	13	117,000	300	None	1,200	By sewers and private scavenging.	By sewers	By private scavenging	657		By sewers					Wholly													114
			CHESTER	DEE	Corporation	31,100	26,000	Public	36	936,000		6		By sewers and private scavenging	By sewers	By private scavenging			By sewers					Wholly													115
			CONGLETON	MERSEY	Corporation	12,000	1[illegible],000	Both			60	1	2,105		By sewers and watercourses	By private scavenging	1,252		By sewers and surface-streams.	By sewers	..	300,000	30	Wholly				...		...					..		116.
			CREWE	"	Local Board	16,000	16,000	Public			51	None	2,[illegible]00	By sewers and public scavenging	By sewers	By scavenging	750	24	By sewers	By sewers	..	801,000	50	Wholly, after precipitation						By contract (privies and ash-pits).	300	Nil			300	4 5	117
			[illegible]AINFIELD	"	Local Board	16,000	14,000	Public	12	168,000	40	None	2,0[illegible]		By sewers	By scavenging (private for ashes, public for streets)		29	By sewers	By sewers	By manholes	..		Wholly						...							118
			MACCLESFIELD	"	Corporation as L. B	37,000	25,000	Public	10[illegible]	412,500	220	None	2,200		By sewers	By public and private scavenging.	1,001	35	By sewers and surface-drains	By sewers				Wholly						By board					..		119
		120.	TRANMERE	"	Local Board	15,000	15,000	Public	24	360,000	2,000		2,000	By sewers and public scavenging	By sewers	By scavenging	1,059		By sewers	By sewers				Wholly						By contractor	400	Nil			400	6 1	120
			WALLASEY	"	Local Board	13,500	11,500	Public	30	352,000	586	None	1,763	By sewers and public scavenging	By sewers and to cesspools	By scavenging	843	26	By sewers	By sewers				Wholly						By contractor	400	Nil			400	7 1	121
	Lancashire		ACCRINGTON	RIBBLE	Local Board	2[illegible],000	[illegible]						General	By sewers and scavenging	By sewers	By public scavenging			By sewers	...	By down spouts			...		Wholly				...					350	3 4	122
			ASHTON-UNDER-LYNE	MERSEY	Corporation	3[illegible],000	3[illegible],000	Public	12	4[illegible]8,000	2[illegible]0	9	6,[illegible]	By sewers and public scavenging	By sewers	By scavenging	600		By sewers	By sewers				Wholly	..	...				By corporation	1,046	95	....		1,5[illegible]0	9 5	123
			[illegible]ETON	"	Local Board	7,000	6,[illegible]00	Both	7	4[illegible],000	20	None	1,[illegible]00	By sewers and private scavenging	By sewers	By scavenging (private for ashes, public for streets)	2,420	33	By sewers	By sewers				Wholly						By board (street-sweepings only).	70	Nil	...		70	2 4	124
			BACUP		Local Board	2[illegible],000	1[illegible],000	Both			61		6[illegible]0	By sewers and public scavenging	By sewers and to cesspools	By scavenging		44	By sewers and surface streams	..		108,000	8		Wholly			..		By contractor	400	Nil			400	5 5	125
			BLACKBURN	RIBBLE	Corporation	81,000	6[illegible],000	Public			9[illegible]	None	13,500	By sewers and public scavenging	By sewers	By scavenging	2,300	43	By sewers	By sewers		2,000,000	29			Wholly				By corporation	3,10[illegible]	460			2,620	7 8	126
			[illegible]	"	Local Board	7,000	6,500	Both		249,660	600	None	850	By sewers and private scavenging	By sewers	By scavenging for ashes only	35[illegible]	31	By sewers	By sewers		1,000,000	154	Wholly				..		By board (ashes only)	100	Nil			100	3 4	127
			BOLTON	MERSEY	Corporation as L. B	8[illegible],000	50,000	Public	21	1,000,000	300	None	6,800	By sewers and scavenging	By sewers	By scavenging	1,000	47	By sewers	By sewers	By manholes and down spouts.	1,725,780	35	Wholly						...	3,172	1,568	....	.....	1,604	4 8	128
			BURNLEY	RIBBLE	Corporation	35,000	[illegible],000	Public	15	52[illegible],000	500	None	3,000	By sewers and private scavenging	By sewers	By scavenging		40	By sewers		By shafts and down spouts.			Wholly					..	By corporation					..		129
			BURY	MERSEY	Improvement Commissioners.	30,000	29,000	Public	20	550,000	147	None	3,705	By sewers and public scavenging.	By sewers	By scavenging	2,000	30	By sewers	By sewers	None			Wholly			...			By commissioners	700	100			600	4 8	130
	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.

14		23.	24.	25.	32.	33.	34.	35.	36.	37.	38.
1,0		360,000	28		290	100			190	2·3	131.
4		250,000	50	Wholly							132.
7		57,000	8	Wholly	50				50	1·5	133.
9		864,000	45	Wholly							134.
15,0	uts, & venti-lators.	25,000,000	49	Wholly	2,385	10,519			41,866	19·7	135.
49,0				Wholly	0,000	8,300			11,700	7·0	136.
1,0				Wholly	237				237	14·2	137.
				Wholly	300				300	5·1	138.
6				Partially	45*						139.
	down	2,660,000	31	Wholly					4,678	13·1	140.
					50	Nil			50	1·8	141.
4,0		420,000	30		550	95			455	4·5	142.
1,0				Wholly	70	Nil			70	2·8	143.
8,5		1,500,000	16	Wholly	3,450				3,450	8·9	144.
3,4				Wholly	2,200				2,200	11·2	145.
6,0				Wholly	300	Nil			300	1·8	146.
16,4				Wholly	6,871	3,873			2,998	5·9	147.
3,1		650,000	37	Wholly	1,000	600			400	5·3	148.
1,7				Wholly							149.
1		318,000	53	Wholly	126	Nil			126	4·7	150.
5				Partially							151.
4,5		1,000,000	38	Wholly	1,045				1,045	8·4	152.
7		237,000	36	Wholly							153.
5				Wholly							154.
2,		500,000	20	Wholly	500*	Nil			500†	4·4	155.
				Wholly	30				30	1·2	156.
1,				Wholly	800				800	4·7	157.
											158.
1,		700,000	70	Wholly							159.
16,	down	6,000,000		Wholly	1,490				11,490	19·3	160.
1,				Wholly							161.
		1,000,000	50	Wholly							162.
7,		2,500,000	56	Wholly							163.
2,				Wholly							164.
15,				Wholly							165.
1		23.	24.	25.	32.	33.	34.	35.	36.	37.	38.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
NORTH WESTERN	Lancashire	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	26	[illegible]	[illegible]	[illegible]	[illegible]	By sewers and [illegible] scavenging.	By sewers	By scavenging	[illegible]	15	By sewers	By sewers	By down spouts	[illegible]	28				Wholly			By [illegible]	[illegible]	[illegible]			190	2 3	131
		132.	DENTON	Mersey	Local Board	5,000	5,000	Both		80,000	30	None	100	By sewers and private scavenging	By sewers	By private scavenging	1,000		By sewers	By sewers		250,000	50	Wholly													132
		133.	ROYLESDEN	,,	Local Board	8,000	7,500	Public	6	42,000	12	None	700	By sewers and private scavenging.	By sewers	By scavenging (private for ashes, public for streets).	1,144	33	By sewers	By sewers	...	57,000	9	Wholly						By board (streets only)	50				50	1 5	133
		134.	HEYWOOD		Local Board	23,000	19,000	Public		392,000	110	None	900	By sewers and private scavenging.	By sewers	By private scavenging	1,250	10	By sewers	By sewers		861,000	15	Wholly													134
		135.	LIVERPOOL		Corporation	510,000	510,000	Public	25	12,750,000	11,000	None	15,000	By sewers and public scavenging.	By sewers	By scavenging		46	By sewers	By sewers	[illegible]	25,000,000	13	Wholly						By corporation	52,985	40,519			11,566	19 7	135
		136.	MANCHESTER	,,	Corporation	400,000	400,000	Public	16⅔	6,666,000	10,000	None	40,000	By sewers and public scavenging.	By sewers	By scavenging	20,000	33	By sewers	By sewers	By down spouts... [cisterns]			Wholly						By corporation	20,000	8,700			11,700	7 0	136
		137.	MOSS SIDE	,,	Local Board	4,000	4,000	Public	16⅔	66,600	400	None	1,000	By sewers and public scavenging.	By sewers	By scavenging			By sewers	By sewers				Wholly						By contractor	237				237	14·2	137
		138.	NEWTON HEATH	,,	Local Board	14,000		Public	16⅔					By sewers and public scavenging.	By sewers	By scavenging	1,335	36	By sewers	By sewers				Wholly						By contractor	300				300	5 1	138.
		139.	NEWTON IN MACKERFIELD	,,	Local Board	7,000	5,000	Private wells only			40	1	600	By sewers and public scavenging.	By sewers	By scavenging	1,400	28	By sewers	By sewers				Partially	Partially					By contractor for ashes, by board for streets.	45*						139.
		140.	OLDHAM	,,	Town Council	86,000	86,000	Public	23	1,978,000	700	None		By sewers and public scavenging.	By sewers	By scavenging	4,6[illegible]5	36	By sewers	By sewers	By manholes and down spouts.	2,660,000	31	Wholly						By corporation					4,678	13 1	140
		141.	ORMSKIRK	Ribble	Local Board	6,500	6,000	Public	20	170,000	120	None		By sewers and private scavenging.	By sewers	By scavenging (private for ashes, public for streets).			By sewers	By sewers							Wholly after precipitation.			By board (streets only)	[illegible]	Nil			50	1 8	141
		142.	OVER DARWEN	,,	Local Board	21,000	14,000	Public		210,000	60		1,000	By sewers and public scavenging.	By sewers	By scavenging	12,000		By sewers	By sewers		420,000	30		Wholly					By contractor	5[illegible]	95			455	4 5	142
		143.	PENNINGTON	Mersey	Local Board	6,000	5,000	Private		10,000	6	None	1,000	By sewers and public scavenging.	By sewers	By scavenging	160	30	By sewers	By sewers				Wholly						By board	70	Nil			70	2 8	143
		144.	PRESTON	Ribble	Corporation as L. B.	93,000	93,000	Public	21	2,250,000	2,500	None	8,500	By sewers and public scavenging.	By sewers	By scavenging	2,800	15	By sewers	By sewers	By down spouts	1,5[illegible]	16	Wholly						By contractor for ashes &c., by board streets.	3,150				3,150	8 9	144
		145.	ROCHDALE	Mersey	Corporation	47,000		Public	13	675,000	300	None	3,100	By sewers and public scavenging	By sewers	By scavenging	770	17	By sewers	...				Wholly						By corporation	2,200				2,200	11 2	145
		146.	ST. HELENS	,,	Corporation	40,000	40,000	Public	15	600,000	250	None	6,000	By sewers and public scavenging.	By sewers	By scavenging	6,580	30	By sewers	By sewers				Wholly						By contractor	300	Nil			300	1 8	146.
		147.	SALFORD	,,	Corporation	121,500	121,500	Public	17½	2,126,250	1,531	None	16,448	By sewers and public scavenging.	By sewers	By scavenging	3,500	33	By sewers	By sewers	None			Wholly						By corporation	6,871	3,873			2,998	5 9	147.
		148.	SOUTHPORT		Corporation	18,000	17,500	Both	25		1,100	None	3,100	By sewers and public scavenging.	By sewers	By scavenging		24	By sewers			650,000	37	Wholly						By corporation	1,000	600			400	5 3	148.
		149.	STALEYBRIDGE	Mersey	Corporation as L. B.	25,000	21,000	Both	20	400,000	150	None	1,701	By sewers and private scavenging.	By sewers	By scavenging (private for ashes, public for streets).	1,000	40	By sewers	By sewers				Wholly						By corporation, streets [illegible]							149
		150.	[illegible]		Local Board	[illegible]	6,0[illegible]	Public	[illegible]	180,000	70	None	[illegible]	By sewers and public scavenging.	By sewers	By scavenging	1,[illegible]	[illegible]	By sewers	By sewers		318,600	53	Wholly						By contractor	126	Nil			126	4 7	150
		151.	TYLDESLEY, WITH SHAKERLEY.	,,	Local Board	7,000	5,000	Both		57,000	6		500	By sewers and private scavenging.	By sewers	By private scavenging (ashes only)	240		By sewers	By sewers				Partially	Partially					...							151.
		152.	WARRINGTON		Corporation as L. B.	[illegible]	26,000	Both		3[illegible]	300	None	4,500	By sewers and public scavenging.	By sewers	By public scavenging	9[illegible]0		By sewers (roof-water collected for use).			1,000,000	58	Wholly						Ashes &c by contract streets by corporation	1,045				1,045	8 1	152.
		153.	WATERLOO WITH SEAFORTH.		Local Board	6,500	6,500	Public	25	162,500	1,165	None	776	By sewers and public scavenging.	By sewers	By scavenging	688	35	By sewers			237,000	30	Wholly						Ashes &c. by contract, streets by board.							153.
		154.	WAVERTREE	Mersey	Local Board	7,000	4,660	Public	25	116,500	250	None	500	By sewers and public scavenging.	By sewers	By scavenging	849		By sewers	By sewers				Wholly						Ashes &c by contract, streets by board.							154
		155.	[illegible]		Local Board	[illegible]	[illegible]	Both			1,500	None	2,165	By sewers and public scavenging.	By sewers	By scavenging					By down spouts	500,000	20	Wholly						By contract ashes &c	50[illegible]*	Nil			500*	4 4	155
		156.	[illegible]STLEIGH	Mersey	Local Board	[illegible]	[illegible]	Private		10,000	10	None	[illegible]	By sewers and private scavenging.	By sewers and surface streams	By scavenging (private for ashes, public for streets).	1,741	30	By sewers and surface streams.	By sewers				Wholly						By board [illegible]	30				30	1 2	156
		157.	[illegible]	[illegible]	Corporation as L. B.	41,000	[illegible]	Public	18	700,000	500	None	1,500	By sewers and public scavenging.	By sewers	By scavenging		16	By sewers					Wholly						By contractor	8[illegible]				800	4 7	157
YORK	West Riding	158.	BARNSLEY	Ouse	Local Board	20,000	18,000	Public							By sewers			27	By sewers		None																158
		159.	BATLEY	,,	Corporation as L. B.	20,000	10,000	Both	20		100	None	1,300	By sewers and private scavenging.	By sewers	By private scavenging	2,038		By sewers (roof-water collected for use)	By sewers		700,000	70	Wholly													159.
		160.	BRADFORD	,,	Corporation as L. B.	143,000		Public		5,000,000	1,500	None	16,000	By sewers and public scavenging.	By sewers	By scavenging	11,000	36	By sewers	By sewers	By shafts and down spouts.	6,000,000		Wholly						By contractor	11,490				11,490	19·3	160.
		161.	[illegible]		Corporation as L. B.	[illegible]	23,[illegible]	[illegible]	20	400,000	300	20	1,216	By sewers and private scavenging.	By sewers	By private scavenging	1,568	51	By sewers	By sewers	None			Wholly							...				...		161.
		162.	DONCASTER	,,	Corporation as L. B.	20,000	20,000	Public	40	800,000				By sewers and private scavenging	By sewers	By scavenging (private for ashes, public for streets).		26	By sewers	By sewers		1,000,000	50	Wholly													162.
		163.	[illegible]	,,	Corporation as L. B.	[illegible]	15,000	Public	50	2,000,000	1,925	None	7,700	By sewers and scavenging	By sewers	By scavenging	1,350	17	By sewers	By sewers	By shafts	2,500,000	56	Wholly						[illegible] occupiers at scale of charg[illegible]							163.
		164.	HUDDERSFIELD	,,	Town Council	25,000	25,000	Public		400,000	950	None	2,000	By sewers and public scavenging.	By sewers	By scavenging	660	33	By sewers	By sewers				Wholly													164
		165.	SHEFFIELD	,,	Corporation as L. B.	225,000	180,000	Public			1,500	7	15,000	By sewers and private scavenging.	By sewers	By scavenging (public for streets & public & private for ashes &c.)	5,700	39	By sewers					Wholly													165

* Ashes &c. only.

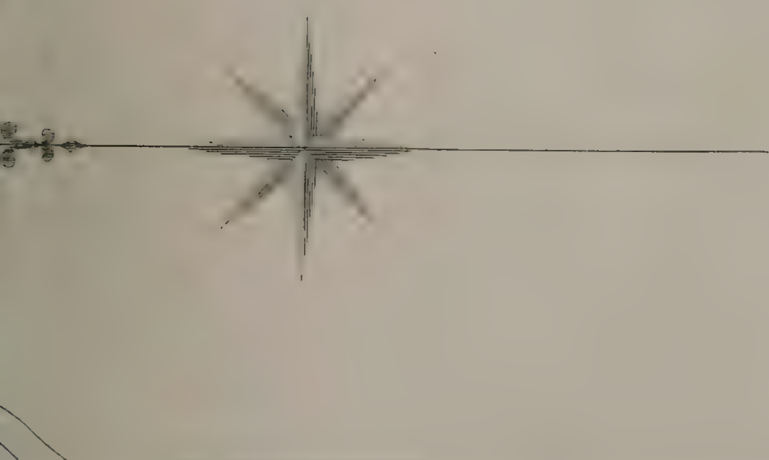
† Ashes and privy refuse only.

.	2.	23.	24.		32.	33.	34.	35.	36.	37.	38.
e	...	200,000	33	Who...	...	...	...	...	...	...	166.
e	...	...	...	Who...	...	...	...	...	...	...	167.
...	and down	1,300,000	50	Who...	724	200	...	...	524	4·8	168.
e	...	17,000	7	Who...	...	...	...	...	...	...	169.
...	...	...	...	pre Who..	2,200	150	...	...	2,050	22·4	170.
e	...	...	...	Who..	26	12	...	...	14	0·8	171.
...	...	...	...	Who..	420	140	...	...	280	2·7	172.
e	...	...	...	Whets	300	60	...	...	240	3·8	173.
e	...	...	...	Who..	...	...	...	...	...	...	174.
e	...	...	...	Whoes	Nil	100	100	1·0	...	...	175.
e	...	432,000	18	Whoc.	...	...	...	...	110	1·1	176.
...	...	...	...	Who..	11,017	1,182	...	...	9,835	17·5	177.
e	...	...	...	Part..	1,000	263	...	...	737	4·9	178.
...	...	...	...	(r Wh..	...	...	...	...	...	...	179.
...	and down	...	...	Part..	902	180	...	...	722	5·6	180.
...	...	...	...	Wh..	567	317	...	...	260	3·3	181.
	...	130,000	26	...	85	20	...	...	65	3·1	182.
e	...	...	...	Wh..	15	Nil	...	...	15	1·2	183.
...	...	...	...	Wh..	...	...	...	...	...	...	184.
e	...	2,500,000	74	Wh..	1,650	Nil	...	...	1,650	11·3	185.
	...	...	...	Wh..	900	70	...	...	830	15·3	186.
e	...	...	...	Wh..	...	...	...	...	...	...	187.
...	and down	...	...	Wh..	...	...	...	...	...	...	188.
e	boxes and	3,000,000	48	Par..	6,119	3,208	...	...	2,911	11·2	189.
e	...	...	...	Wh..	9,001	9,631	630	1·3	...	...	190.
e	...	...	...	Wh..	983	658	...	...	325	5·2	191.
e	...	...	...	Par..	18,205	8,935	...	...	9,270	11·7	192.
...	...	5,000,000	78	Wh..	33,805	22,962	...	...	10,843	5·8	193.
	...	...	...	Wh..	1,000	Nil	...	...	1,000	4·6	194.
	...	...	...	Wh..	1,050	400	...	...	650	3·2	195.
...	pes ...	1,100,000	41	Wh..	2,000	1,700	...	...	300	2·7	196.
...	tings ...	...	...	Wh..	...	...	...	...	...	...	197.
...	...	...	...	Wh..	...	...	...	...	...	...	198.
...	...	...	...	Wh..	...	...	...	...	...	...	199.
...	...	...	...	Wh..	...	...	...	...	...	...	200.

2. 23. 24 32. 33. 34. 35. 36. 37. 38.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
[illegible]	West Riding	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Public			150	None	[illegible]	By sewers and private scavenging.	By sewers	[illegible]			By sewers			[illegible]	[illegible]	Wholly													[illegible]
		[illegible]	[illegible]	Mersey	Local Board	[illegible]		Private			[illegible]	None	600	By sewers and private scavenging.	By sewers	[illegible]			By sewers					Wholly													167
		[illegible]	[illegible]AKEFIELD	[illegible]	Corporation as L. B.	[illegible]	[illegible]	Public	27	700,000	616		[illegible]	By sewers and public and private scavenging.	By sewers	[illegible]	[illegible]	27	By sewers	By sewers	[illegible]	[illegible]	50	Wholly						By board	721	[illegible]			524	4·8	168
YORK	East Riding	[illegible]	[illegible]	[illegible]	Local Board	[illegible]	[illegible]	Private			12	None	[illegible]	By private scavenging	By sewers and to garden	By private scavenging	240	17	By sewers			17,000	7	Wholly after precipitation.													[illegible]
	North Riding	[illegible]	[illegible]		Corporation as L. B.	[illegible]	[illegible]	[illegible]						By sewers and public scavenging.	By sewers	By scavenging			By sewers	By sewers				Wholly						By corporation	[illegible]	[illegible]			2,050	22·4	170
	Durham	[illegible]	[illegible]CASTLE	Tees	Local Board	[illegible]	[illegible]	Public	16	[illegible]	253	None	100	By sewers and private scavenging.	By sewers	By scavenging	176	26	By new and old sewers	By old sewers	None			Wholly						By board (ashes only)	26	[illegible]			14	0·8	171
		[illegible]	[illegible]	„	Corporation as L. B.	[illegible]	[illegible]	Both		1,500,000	[illegible]			By sewers and public scavenging.	By sewers	[illegible]		[illegible]	By sewers	By sewers				Wholly						By corporation	120	110			280	2·7	172
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11	[illegible]	[illegible]	None	[illegible]	By sewers and private scavenging.	[illegible]	By private scavenging, public for ashes, public for streets).			[illegible]	By sewers or private				Wholly						By corporation (street only).	[illegible]	[illegible]			21	[illegible]	[illegible]
		174.	HOUGHTON-LE-SPRING.	Tees	Local Board	5,500	4,800	Both	...	66,000	6	None	825	By sewers and public and private scavenging.	By sewers	By public and private scavenging.	42	...	By surface-streams, roof-water tanks, &c.	By sewers				Wholly						By board							174
		[illegible]	[illegible]	„	Corporation as L. B.	[illegible]	[illegible]	[illegible]	23	[illegible]	[illegible]	None	[illegible]	By sewers and public scavenging.	By sewers	By scavenging		20	By sewers					Wholly						By contractors, ashes and nightsoil only	Nil	100	100	1·0			[illegible]
		[illegible]	[illegible]		Local Board	[illegible]	[illegible]	[illegible]			110	None	[illegible]	By sewers and public scavenging.	By sewers	[illegible]	[illegible]	21	[illegible]	By sewers		[illegible]	18	Wholly						By board, ashes, &c. only					[illegible]	[illegible]	[illegible]
	Northumberland	[illegible]	[illegible]	Tyne	Corporation	[illegible]	[illegible]	Both	[illegible]	[illegible]				By sewers and public scavenging.	By sewers	[illegible]	[illegible]	21	By sewers, &c., water for party, &c.	By sewers				Wholly						By corporation	[illegible]	[illegible]			[illegible]	[illegible]	177
		[illegible]	[illegible]		Local Board	[illegible]	[illegible]	Both	11		496	None		By sewers and private scavenging.	By sewers	By scavenging, private for ashes, public for streets).		26	By sewers and water collected for use.	By sewers				Partially (nearly all).			Partially*			By contractor	[illegible]	263			737	4·9	178
		179.	WALKER	Tyne	Local Board	9,000	9,000	Public							By sewers				By sewers	By sewers				Wholly						By board							179
	Cumberland	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Both	28	850,000	General			By sewers	By sewers	By scavenging	[illegible]	[illegible]	By sewers	By sewers	By chimneys and down spouts.			Partially			Partially			By board	[illegible]	180			722	5·6	180
		181.	WHITEHAVEN		Local Board	19,000	19,000	Public	53	1,000,000					By sewers	By scavenging			By sewers		By gratings			Wholly						By board	567	317			260	3·3	181
	Westmoreland Monmouthshire	[illegible]	ABERGAVENNY	Usk	Improvement Commissioners.	5,000	5,000	Both	18	90,000	300	6		By sewers and public scavenging.	By sewers	By scavenging		26	By sewers	By sewers		130,000	26		Wholly					By commissioners	85	20			65	3·1	182
		[illegible]	ANTEG	„	Local Board	3,000	700	Private			60	None		By sewers	By sewers	By scavenging			By sewers	By sewers				Wholly						By board	15	Nil			15	1·2	[illegible]
	North Wales	184.	KNIGHTON	Severn	Local Board	1,700	1,600	Public						By sewers and scavenging	By sewers				By sewers					Wholly													184
WALES	South Wales	[illegible]	[illegible]		Local Board	[illegible]	[illegible]	Both		[illegible]	[illegible]	None	[illegible]	By sewers and scavenging	By sewers	[illegible]	708	12	By sewers	By sewers		2,500,000	71	Wholly						By contractor	[illegible]	Nil			1,950	11·3	185
		186.	LLANELLY		Local Board	13,000	6,000	Public	20	120,000	120	4		By sewers and public scavenging.	By sewers	By scavenging	900	30	By old and new sewers	By sewers				Wholly						By board	900	70			830	15·3	186
		187.	MOUNTAIN ASH	Taff	Local Board	8,000		Both			220	None	800	By sewers and private scavenging.	By sewers	By public scavenging			By old and new sewers					Wholly													187
		[illegible]	SWANSEA		Local Board	50,000	20,000	Public	40	800,000	4,000							30	By sewers		By shafts and down spouts.			Wholly													188
		[illegible]	[illegible]		[illegible] Commissioners	[illegible]	[illegible]	Public	33	[illegible]	[illegible]	None	[illegible]	By sewers and public scavenging.	By sewers	By scavenging	[illegible]	1	By sewers	By sewers	By special boxes &c.	[illegible]	18	Partially			Partially			By commissioners	6,119	3,208			2,911	11·2	189
		[illegible]	[illegible]		Board of [illegible]	[illegible]	[illegible]	Both	26	[illegible]	[illegible]	None	[illegible]	By sewers and public scavenging.	By sewers	By scavenging	[illegible]	25	By sewers	By sewers				Wholly						By board	[illegible]	[illegible]	[illegible]	1·3			190
		[illegible]	[illegible]	[illegible]	Board of Police	[illegible]	[illegible]	Both	15	[illegible]	[illegible]	None	[illegible]	By sewers and public scavenging.	By sewers	By scavenging	[illegible]	[illegible]	By sewers		None			Wholly						By board	[illegible]	[illegible]			325	5·2	191
SCOTLAND		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	Public	40	[illegible]	General	None		By sewers and public scavenging.	By sewers	By scavenging	1,191	[illegible]	By sewers	By sewers	None			Partially			Partially			By council	[illegible]	[illegible]			1,270	11·7	192
		[illegible]	[illegible]	[illegible]	Board of Police	[illegible]	[illegible]	Public	18	[illegible]	[illegible]		[illegible]	By sewers and public scavenging.	By sewers	By scavenging	[illegible]	[illegible]	By sewers	By sewers		[illegible]	78	Wholly						By board	[illegible]	[illegible]			[illegible]	5·8	193
		194.	GREENOCK	„	Board of Police	52,000	51,000	Public	60	14,917,000		None		By sewers and public scavenging.	By sewers	By scavenging	1,125	61	By sewers	By sewers				Wholly						By contractor	1,000	Nil			1,000	4·6	194
		[illegible]	[illegible]	„	Board of Police	[illegible]		Public	21			None	2,000	By public scavenging	Thrown on ashpits	By scavenging		[illegible]	By sewers	By sewers				Wholly						By board	1,050	400			650	3·2	195
		[illegible]	[illegible]	Tay	Board of Police	27,000	27,000	Both	13	[illegible]			170	By sewers and public scavenging.	By sewers	By scavenging	[illegible]	35	By sewers	By sewers	By special pipes	1,100,000	41	Wholly						By board	[illegible]	1,700			[illegible]	2·7	196
		197.	BELFAST		Town Council	170,000		Both					General	By sewers and public and private scavenging.		By public and private scavenging.		35	By sewers		By gully gratings			Wholly													197
IRELAND		198.	CLONMEL		Improvement Commissioners	11,000	11,000	Both					General		By sewers				By sewers		By gratings			Wholly													198
		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	Public	15	[illegible]				By sewers and private scavenging.	By sewers	By private scavenging for ashes.			By sewers					Wholly													[illegible]
		200.	RATHMINES		Improvement Commissioners.	18,000		Public	20					By sewers and private scavenging.	By sewers	By private scavenging for ashes.			By sewers					Wholly													[illegible]
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.	37.	38.

* A small portion only.



All magnified 320 diameters.


COMMITTEE OF THE BRITISH ASSOCIATION
ON THE TREATMENT AND UTILIZATION OF SEWAGE
Plan of Breton's Sewage Farm
near Romford.
1870.
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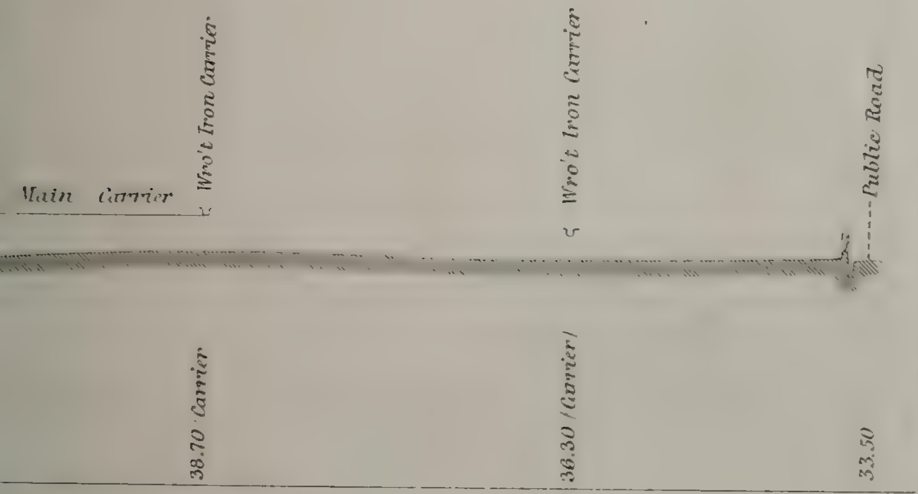
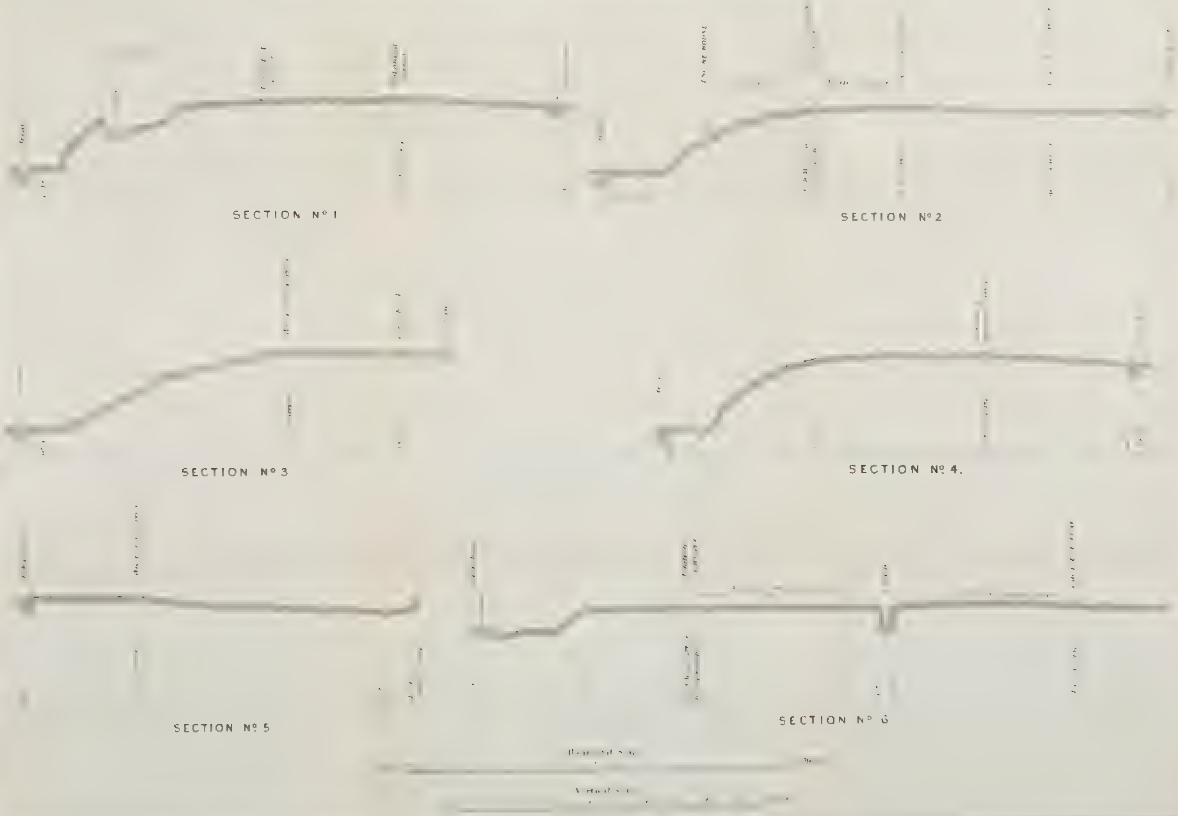
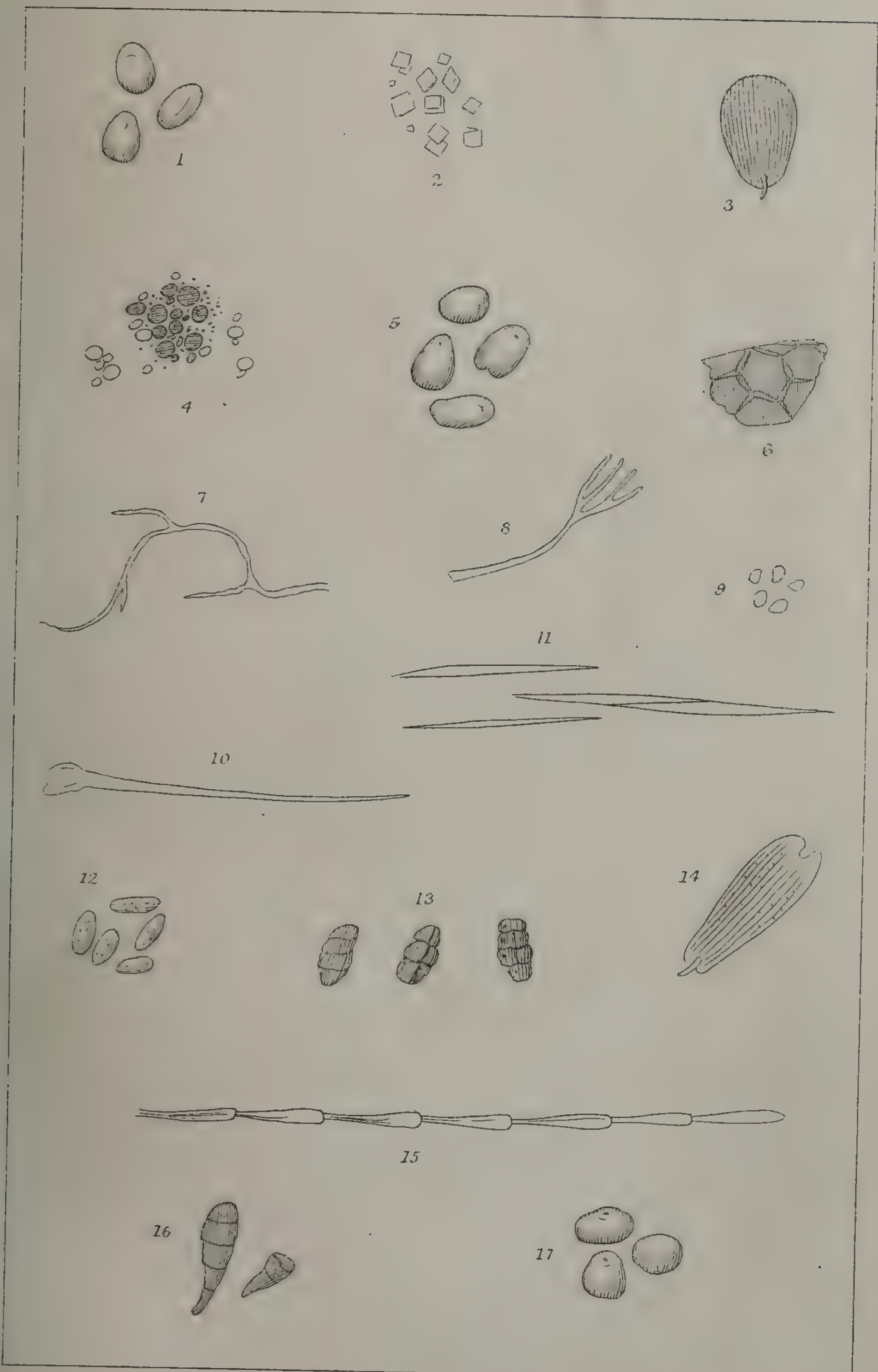


SECTION No 2.

All magnified 320 diameters.

SECTIONS AT BRETON'S FARM ROMFORD, ESSEX, 1870.





All magnified 320 diameters.

decaying leaves of cabbages and other plants (fig. 16), often accompanied by other moulds, especially *Cladosporium.*

No. 4. I could detect nothing but one or two starch-granules, a few minute inorganic particles like very fine sand, and a little granular matter.

No. 2. This was richest in organisms of all the samples, containing quite a variety of subjects. The starch-granules were variable in form and size (fig. 5); in most the hilum was quite distinct, in some the parallel lines: for better security against error in observation they were tested with iodine. Fragments of cellular tissue were also present (fig. 6), and granular matter slightly discoloured, which resembled vegetable tissue in a state of decay and disintegration (fig. 4). Several fragments of delicate branched filaments were also present (fig. 7), greatly like the mycelium of some minute fungus; also the branched upper portion of a thread very similar to those of *Penicillium* (fig. 8). Minute ovate spores were also present (fig. 9), reminding one very much of the spores of one of the white moulds, such as *Aspergillus* or *Penicillium.* Larger spores were also present, of an elliptical form, variable in size and proportions from ·00035 in. to ·0005 in. in length by ·00025 in. in width, of a yellowish tint, and rather granular within (fig. 12). In size and character these resembled the spores of *Cladosporium* in the early stage, before the septa are formed. Still larger spores were found, but rarely, that were coloured brownish, ·00075 in. in length, and ·0005 in. in breadth, divided transversely by three or four septa slightly constricted at each septum; and again with each cell divided in the opposite direction, so that the spores were multilocular, or fenestrate (fig. 13). Fragments of woody fibre (fig. 11) were also present, and a vegetable hair, rather bulbous at the base, consisting of but a single cell (fig. 10).

The animal kingdom was represented by portions of the fibrils of feathers (fig. 15) and the scale of a Lepidopterous insect (fig. 14). Fragments of inorganic matter were also present in very minute rather angular pieces of what might have been glass or sand; but *this* is only a guess.

No. 1 was largely charged with minute cubic and rhombic crystals, which polarized well (fig. 2), some starch-granules (fig. 1), and the scale of a Lepidopterous insect (fig. 3). Besides these was a quantity of vegetable granular matter, broken up cells, and a small quantity of minute quartz-like fragments.

As No. 1 and No. 2 were derived from the same locality, differing only in the quantity of air passed through the wool, and, it is presumed, in the precise time at which it was passed, one cannot help thinking that the same sewer would at different periods of the same day give a different result in the organisms with which the air is charged. No fungi-spores were detected in No. 1, and none of the curious little crystals so plentiful in No. 1 were visible in No. 2.

A more extended series of examinations, which would of course occupy considerable time and attention, would be of value in furnishing data for determining problems which are sure to suggest themselves during inefficient or incomplete examinations.

Report on Observations of Luminous Meteors, 1869–70. *By a Committee, consisting of* James Glaisher, *F.R.S., of the Royal Observatory, Greenwich,* Robert P. Greg, *F.G.S., F.R.A.S.,* Alexander S. Herschel, *F.R.A.S., and* Charles Brooke, *F.R.S., Secretary to the Meteorological Society.*

In resuming the subject of their Report to the British Association for the past year, the Committee have to regret the loss which they have sustained, since the preparation of the last Report, by the death, on the 1st of February last, of a late member of this Committee, Prof. E. W. Brayley, to whose appointment by the British Association, in the year 1862, to assist in their especial objects, the Committee have been indebted for constant and invaluable aid.

In reviewing for the past year the progress of inquiry, and the results of observations relating to meteors, continued attention towards the establishment of star-shower dates, and their radiant-points, has rewarded Prof. Schiaparelli with the determination of a considerable number of radiant-points, indicating, on certain nights of the year, the earth's passage through well-defined streams of meteoric matter, of which the visual directions of motion, and the concluded parabolic orbits round the sun, are described by Prof. Schiaparelli in a recent memoir, as derived from the observations of Mr. Zezioli at Bergamo, the Table of which is reproduced in the third Appendix of this Report. The meteor-currents thus already indicated will shortly be supplemented or confirmed by the observations recorded at sixteen of the principal Italian observatories*, of which Mr. F. Denza has obtained the cooperation since April last. More than 2000 shooting-stars having been observed during the months of April, May, and June 1870; and the observations, as they continue to accumulate, being communicated for this purpose to Prof. Schiaparelli, the number and distinctive characters of other meteoric showers, besides those of the principal meteor dates in August and November, will thus be ascertained, to which the attention of observers has hitherto been only partially directed.

The Committee are indebted to observers during the past year for the contribution of a large number of observations of bright meteors, and of shooting-stars, recorded during the two chief displays of November 1869 and August 1870, statements regarding the principal results of which are contained in the following Appendices of this Report.

In the catalogue† of the past year the observations of luminous meteors include, as in previous years, all those descriptious of large meteors which have come to the knowledge of the Committee, with the exception of a large number of foreign observations of the great fireball seen in the south-west parts of Europe, on the 8th of September, 1869, of which it is expected that a condensed account will be published before the preparation of another Report, embodying all the principal features of its course. An extraordinary length of path and area of visibility has been assigned to this large meteor, as will hereafter be described.

* Alessandria, Aosta, Bergamo, Florence, Genoa, Girgenti (Sicily), Milan, Moncalieri (Turin), Naples, Padua, Palermo (Sicily), Perugia, Piacenza, Thiene (Vicenza), Urbino, Volpeglino (Tortona).

† The Catalogue, in accordance with a resolution of the General Committee, will not be printed in future Reports; it will be preserved for reference, and the Committee hope to exhibit its principal results in a connected form.

A large number of observations of shooting-stars during the August period (in 1870) are also collected in the Catalogue, while the general appearances of the meteors, and observations of their heights, are described in this Report. It will be seen that while only six fireballs were so well observed in England and Scotland during the past year as to enable their heights to be determined (on the 1st and 11th of October, 6th and 14th of November, and 12th of December, 1869, and on the 20th of August, 1870), the heights of sixteen shooting-stars were obtained during the meteoric shower of the 5th to 11th of August, 1870; and twenty shooting-stars recorded at Greenwich, during the same meteoric shower, were so well recorded at other places that their real heights are at present undergoing calculation.

During the meteoric shower of the 14th of November, 1869, the sky, at places in the south of England, was generally overcast; but at the Royal Observatory, Greenwich, at Stonyhurst in Yorkshire, and at Edinburgh, Glasgow, and Culloden (Inverness-shire) in Scotland, a clear view of the sky was obtained during a portion of the time in which the shower appeared to be at its height; and a large fireball was doubly recorded by the observers at the last two stations, of which the height, obtained by calculation, is recorded with other double meteor-observations in the Appendix. The advantage of maintaining a watch for the phenomenon at such widely distant stations was the more apparent at the last return of the November star-shower, since in America, on the morning of the 14th of November, 1869, the sky was, throughout the United States, so overcast by a fall of snow that no other announcement of the meteoric shower having been seen west of the European continent, with the exception of the brilliant phenomena observed in Florida and California, has hitherto been received by the Committee. The observations of the same shower in Italy, at Port Saïd in Egypt, and at the Mauritius are described in the last Appéndix of the Report. Although the state of the sky was both favourable for its observation in Italy, and partially so at the other stations, it does not appear that a distinct maximum of the shower was observed at any of those points of view; but the number of the shooting-stars observed during the progress of the shower rose and fell, sometimes very rapidly, through a great range of frequency and of the average apparent brightness of the meteors. It may be inferred from these results that the phenomenon of the November star-showers is now rapidly declining in its intensity, and that the stream of the Leonids, if it should be crossed by the earth on the morning of the 14th of November in the present year, will be found to have grown diffuse, and to have scattered itself into groups of less frequent falling stars, with intervening "lulls" or barren intervals, in which observers will be rewarded by the sight of very few meteors, or in which it may happen that, for the space of many minutes, no shooting-stars will be observed.

Following the example set by Prof. Schiaparelli at Milan, and by the Italian astronomers at Turin, Urbino, Rome, Palermo, and at other observatories in Italy, whose collective catalogue of shooting-stars recorded since the beginning of this year now numbers many thousands of observations, to conduct observations of shooting-stars as far as possible on stated nights, at such widely separated stations as to increase the visibility of any meteoric shower which might be traced, the Committee have decided, with a view to contribute to the objects of the same well-devised scheme of observations, to confine their immediate attention for the present to those nights of the year on which long-known and well-established meteoric showers are annually

expected to occur; and for this purpose they have provided star-charts, suitable forms of registry, and directions to observers of the meteors which annually make their appearance, with more or less regularity, on the 1st and 2nd of January, the 19th to the 21st of April, the 5th to the 12th (especially the 10th) of August, the 18th to the 21st of October, the 12th to the 15th of November, and the 11th to the 13th of December. On each of these meteoric dates in the coming year (as their endeavours during the August shower of this year were rewarded with very valuable results) the Committee appeal to observers in distant parts of England to use their ability in mapping and counting the numbers of the meteors seen on the predicted nights, and thus aid in making our hitherto imperfect knowledge of their appearances wider and more certain.

APPENDIX.

I. Meteors Doubly Observed.

1869, October 1st, $8^h\,12^m\,30^s$ P.M., G. M. T., Kent and Brussels. The meteor was well observed by Mr. J. B. Reade at Bishopsbourne, near Canterbury, in England, and at Brussels. The prolongation of the lines of sight at the moment of the meteor's disappearance intersected each other at about ten miles over the neighbourhood of Mons, near the confines of Belgium and France; and the meteor passed almost vertically, at a height of thirty-five miles, over Brussels. If the observed point of disappearance at Bishopsbourne (60° east from south, altitude about 5°) *is moved* 10° *southwards*, without any other alterations being substituted for the original observations, the place of the meteor's disappearance is about fifteen miles above the earth, between Valenciennes and Douay, *near Lille* in the north of France, where M. Le Verrier reports that the meteor was very generally observed). The meteor's height over Brussels was in this case fifty miles; and a more southerly point of disappearance at Bishopsbourne would make the meteor's height greater, and its point of disappearance further south over the provinces of France. The meteor, however, approached very near to the earth, without, as it would appear from the descriptions, producing any audible report. The point of first appearance, "near α Persei," at Bishopsbourne, appears to be situated too far back upon its apparent course to be reconciled with the description of the meteor's course by the stars, as it was observed at Brussels. As the two apparent paths among the constellations intersect each other, when prolonged backwards between Perseus and Aries, on the actual line of flight described at Bishopsbourne, about the constellation Musca (R. A. 40°, N. Decl. 30°), this large meteor's path was probably directed from the radiant-point R_3 (R. A. 41°, N. Decl. 24°) in the latter constellation, which is a conspicuous region of divergence of shooting-stars about the middle of October.

1869, October 11th, $5^h\,4^m\,40^s$ P.M., G. M. T., York and Lancashire. The appearance of this fireball in twilight prevented its course from being noted by the stars; and the uncertainties of estimated altitudes must be expected to introduce corresponding uncertainties in the real path derived from such general observations. The best average height and course which can be elicited from the combined observations at York, Heighington, near Darlington, and Llandudno, nearest to the meteor's flight, is from eighty-four miles over a point between Ashton and Peniston (N. lat. 53° 30′, W. long. 1° 50′) to twenty-eight miles over the neighbourhood of Skipton in Lancashire (N.

lat. 53° 57′, W. long. 2° 6′). The point of disappearance agrees within two or three degrees with the place of disappearance observed by Miss Reade, and measured by Mr. J. B. Reade, at Bishopsbourne in Kent; and the entire course equally exactly represents the apparent elevation (at altitude 30°, due north) as seen at Calne, in Wilts. At these latter places its motion would appear almost vertically downwards, as it was observed at Llandudno and in London. The radiant-point of its approximate course is at R. A. 300°, N. Decl. 14°, near α Aquilæ, where no well-established radiant-point of ordinary shooting-stars has hitherto been detected at that season of the year.

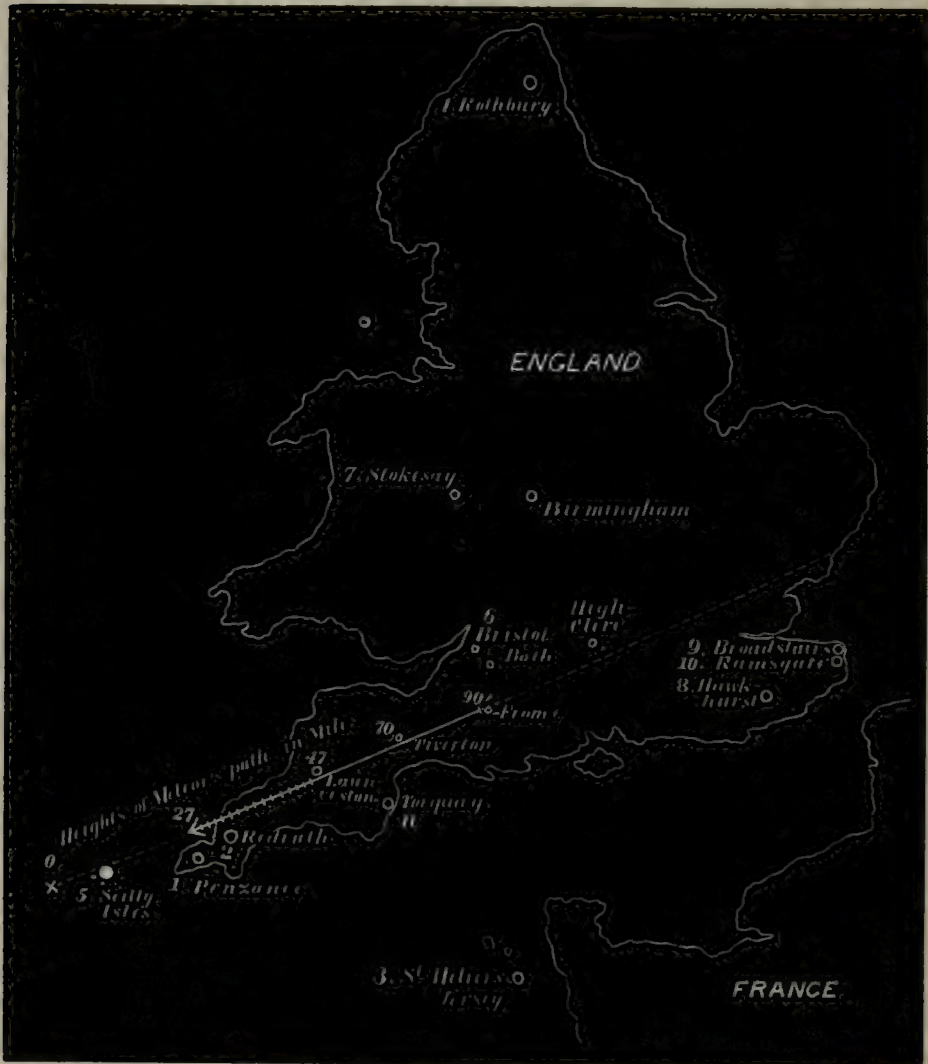
The writer of an extremely interesting article in the 'Daily News,' on the probable real path of the fireball, cites the description of its course by an observer at Sheffield as "apparently from north to south, radiating from the zenith." The place of first appearance was found to be (very nearly as above described) at a height of seventy-six miles over the neighbourhood of Sheffield. At the latter place, very near to the meteor's real course, the observer describes the meteor as having an irregular contour, and compares the apparent size of its surface to one-sixth of that of the moon. As both of the observations at York and Heighington differ from the Sheffield description in showing that the meteor moved towards the west and north, while the real course, concluded from the above observations, would appear at Sheffield radiating from the zenith towards the north-north-west, it is not impossible that the Sheffield observer, by a not uncommon inversion of the points of the compass, misrepresented the actual direction of the meteor's flight, which should have been described as apparently from south to north.

The meteor seen at Leeds, in twilight on some evening about the 25th of October last, was probably identical with this one, as it was so extremely brilliant as to attract the observer's attention while it was still overhead; and it "shot across the zenith towards the sun's place at the time," disappearing, "when a little past the zenith, in sparks and tails." This note of its appearance agrees perfectly well with the description of its apparent shape and magnitude at Sheffield, and it corroborates the observations at York and Heighington, that the meteor moved towards the west. The altitude of 52° in the west-north-west from Leeds, at which the point of extinction, as above determined, probably occurred, might very aptly be described by an observer, who first caught sight of the meteor when it was nearly overhead, as "going out when a little past the zenith."

1869, November 6th, about 6^h 50^m P.M., G. M. T., Cornwall, England, Wales, and Scotland. The great brightness of the fireball and of its persistent streak, which is described by Mr. Pengelly, of Torquay, as having remained in sight fully fifty minutes, rendered it a conspicuous object even beyond the vicinity of places where its luminous course was nearly through the zenith. A comparison of several published descriptions of the meteor, communicated to the British Meteorological Society by Mr. A. S. Herschel, places the point of first appearance of the nucleus ninety miles over Frome, in Somersetshire, the first point of the luminous streak at a height of forty-seven miles over Launceston, and its termination, at the extinction of the meteor, twenty-seven miles over the sea very near St. Ives in Cornwall. The whole length of its luminous course was 170 miles, performed in about five seconds, with a velocity of about thirty-four miles per second. The length of the bright streak, which gradually diffused itself in width and assumed a serpentine form, was fifty-four miles, and its greatest width, when it was first seen by Mr. Pengelly at Torquay, was about four miles (Proceedings of the Brit. Meteor. Soc. for June 1870, p. 144). In that paper the meteor's

course is stated to have descended at Broadstairs from 2° north of the zenith; the real direction of its line of flight was from about 2° south of

Fig. 1.

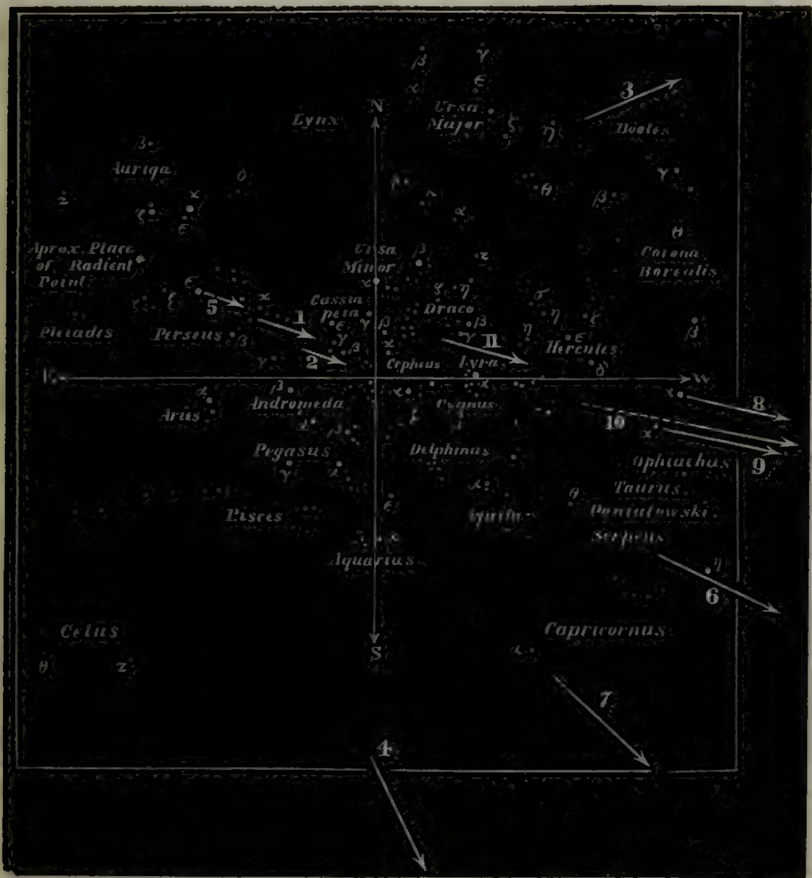


Path of the large fireball of November 6th, 1869. Height and position of the bright streak, and of the meteor's track.

the zenith, as it was there observed by Mr. James Chapman. The track prolonged backwards across the south of England must therefore have passed somewhat more perpendicularly over Kent, or about 10° more nearly from east to west than its real course is shown in the accompanying Map. The radiant-point, which Mr. Herschel states was at R. A. 62°, N. Decl. 37°, would on this account be at a point in smaller right ascension and in lower north declination than that given in the paper. It would thus be nearer to a point in R. A. 54°, N. Decl. 16° (near Aldebaran), from which twelve meteors out of twenty-one shooting-stars observed by Mr. Backhouse, at Sunderland, on the same evening diverged with remarkable uniformity; and four meteors

out of ten, observed on the night of the 4th of November, also appeared to radiate from the same point. The large fireball was accordingly an individual

Fig. 2.



Apparent places of the streak of light left by the large meteor of November 6th, 1869, referred to the stars at:—

1. Penzance.
2. Redruth, Cornwall.
3. St. Helier's, Jersey.
4. Rothbury, Northumberland.
5. Scilly Isles.
6. Bristol.
7. Stokesay, Shropshire.
8. Hawkhurst, Kent.
9. Broadstairs.
10. Ramsgate.
11. Torquay.

of the conspicuous meteor-shower from Taurus, which attracted the attention of observers during the recent returns of the November star-shower, as appearing, although with greatly inferior brilliancy, simultaneously with the meteors of that great display. (See Appendix III., Meteor-showers in November, 1869.)

1869, November 14th, 4^h 47^m A.M., G. M. T., Glasgow and Culloden (Inverness-shire). A considerable fireball during the progress of the November shower attracted the attention of both of the observers, as being opposite in its motion to the general direction of the "Leonids." The meteor was seen due north from Glasgow, in the direction of Culloden (110 miles north from Glasgow), where the meteor passed across the zenith. The apparent parallax is 60°, and the meteor moved horizontally from the north-north-west at a height of sixty miles over the north coast of Inverness-shire, approaching

from the sea at Lossiemouth, and crossing over Inverness towards Kintail. The length of the part of the path observed at Glasgow was seventy-four miles, performed in four seconds of time, with a velocity of eighteen and a half miles per second. The direction of the meteor was from R. A. 12°, N. Decl. 14° in Pisces, very near the position (R. A. 12°, S. Decl. 2°) of a radiant-point T * of shooting-stars observed on the 27th of September, 1864 †. Another meteor of the same group was doubly observed on the 24th of September, 1866; and its velocity was found to be, like that of the present fireball, less than the average velocity of shooting-stars, or about twenty-three miles per second. (Report for 1866, p. 124.)

1869, December 12th, 6^h 13^m 30^s P.M., G. M. T., Glasgow, Hawick, and Oundle (Northamptonshire). Although the description of the meteor's course at the northern stations of Glasgow and Hawick are incomplete, yet on account of their great distance, about 270 miles from Oundle, near Peterborough, where the meteor's path was well recorded by the stars, a good approximation of the meteor's real path is obtained by assuming the well-known position (about R. A. 100°, N. Decl. 35°) of the radiant-point in Gemini of the December meteors to be represented very nearly by the observations of the present meteor intersecting each other, when prolonged backwards at a point about R. A. 125°, N. Decl. 35°. The lowest stars of Ursa Major being less than 20° above the horizon at Oundle, the height of 18° or 20° at which the meteor there was estimated to have passed "below Ursa Major," is evidently overrated; and an altitude of 12° will, with the usual interpretation of estimated altitudes near the horizon, fairly represent the apparent altitude of the meteor's course. After making these preliminary assumptions with respect to the apparent directions of the meteor's flight, it appears, from their comparison together, that the fireball commenced its visible path at a height of 100 miles above Bergen in Norway, and shot with a straight course of about 400 miles, to about fifty miles over Edinburgh, where it disappeared. An observer of its luminous progress at Dundee states that it proceeded with a slow shooting motion, apparently as if forcing its way through the air for about thirty seconds; and the statement indicates the unusually long time occupied by the meteor in its transit across the North Sea. The description of its time of flight at Oundle, by Mr. William Rickett, was that the meteor continued its motion, with an apparent speed by no means rapid, for 15 or 20 seconds. Adopting Mr. Rickett's account as probably the most accurate, and employing his approximate value, or seventeen and a half seconds, for the meteor's time of flight, it follows that the course of about 400 miles was described with a velocity of twenty-three miles per second.

1869, December 29th, 10^h 58^m P.M., G. M. T., London and Sandhurst (Kent). The vertical descent of the meteor in the west at Sandhurst, near Hawkhurst in Kent, and its motion from north-north-west to south-south-east, a few degrees below Jupiter, at Notting Hill, London, indicate the direction of its motion as apparently from the radiant A_{13}, near δ Cassiopeiæ, for the end of December and beginning of January. Adopting this radiant-point for the real direction of its path, the place where the meteor passed near Jupiter, at London, was about forty-five miles high over Winchester; and the meteor passed in the direction of a line from Bath to Chichester, from seventy miles above Amesbury (Wilts) to thirty-five miles above the neighbourhood of Bishops Waltham (Hants). Supposing the meteor's apparent path to have

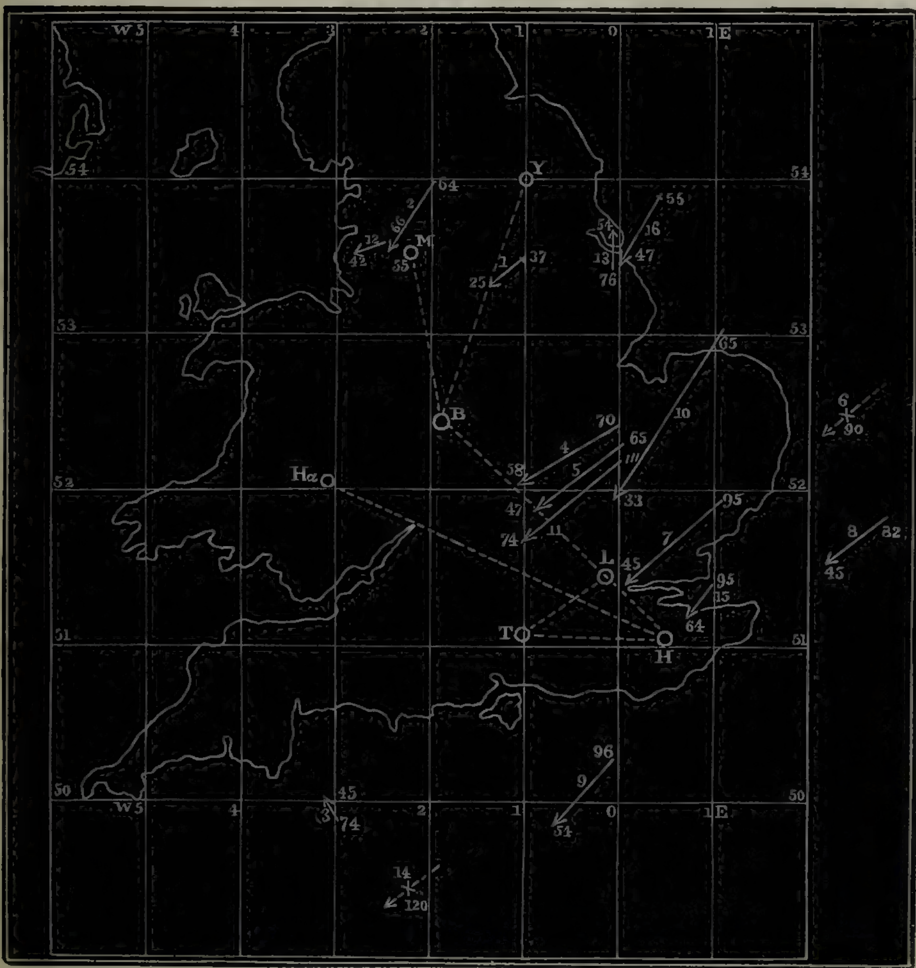
* U in the list of the Report for 1868, p. 403, at R. A. 17°, S. Decl. 10°, enduring from September 6th to November 23rd.

† Monthly Notices of the Royal Astronomical Society for December 9th, 1864.

ended near Jupiter at Notting Hill, this is probably not far from a correct estimate of its real course. The length of the path is forty-seven miles, descending at an inclination of 45°, from the north-west by west towards south-east by east.

1870, August 5th–11th, shooting-stars doubly observed in England. Observations of the August meteors were begun on the 5th, and continued until the 12th of August, 1870, at the request of the Committee, at several stations in England and Scotland, with a view to determine, if possible, the

Fig. 3.



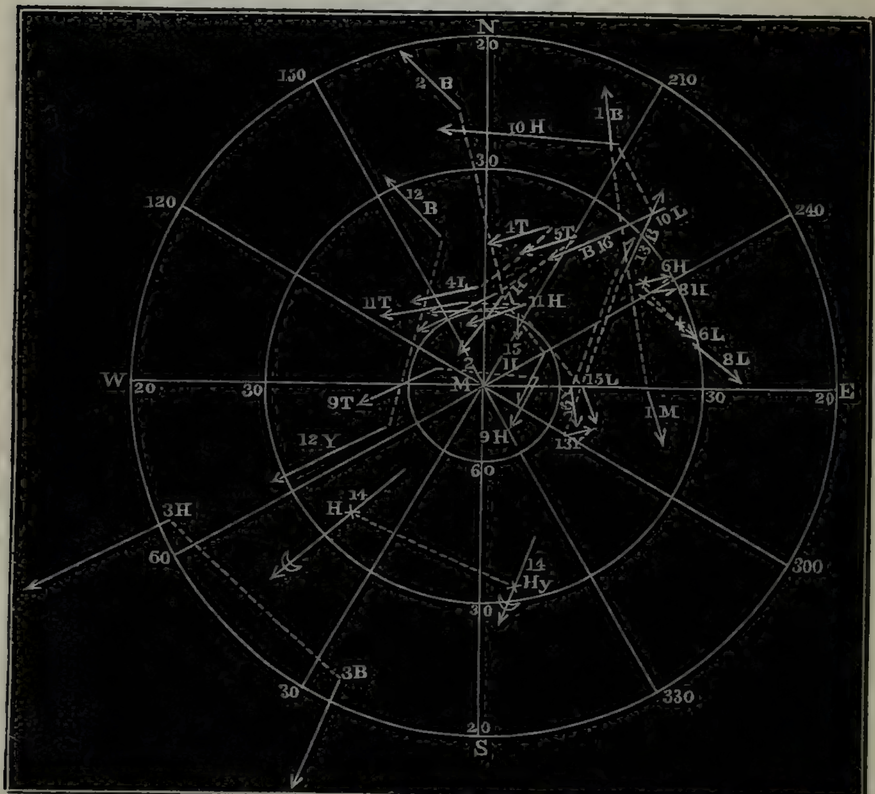
Heights and positions of sixteen shooting-stars doubly observed in England, August 5th–11th, 1870, at (B.) Birmingham, (H.) Hawkhurst, (Ha.) Hay, South Wales, (L.) London, (M.) Manchester, (T.) East Tisted, Hants, (Y.) York*.

real heights and velocities of the August meteors. Independently of the observations made at Greenwich for this purpose, the heights of sixteen shooting-stars were ascertained, the description of whose appearance, and apparent paths, by the several observers are contained at length in the Catalogue.

* *Corrections of the Figure.*—The heights of the Meteors Nos. 15 and 16 are transposed For the beginning and end heights of the Meteor No. 2, *read* fifty miles and thirty-three miles.

In the Table of the results, the times of the observations are those stated by the observers from the best approximations to Greenwich time within their reach, differing from each other occasionally by one or two minutes. The number of the meteors visible, chiefly of the brighter class, in the full-moonlight of the 10th of August last having been small, and regard being paid to the condition that the parallax (fig. 4) of the observed meteor-tracks should be as nearly as possible in the same direction as the base-line joining two corresponding stations upon the map (fig. 3 represents the relative situations of the observers), the errors of time from true Greenwich time at the different stations were very easily detected, and were found to be nearly

Fig. 4.



Adopted apparent paths of sixteen shooting-stars doubly observed in England, August 5th–11th, 1870, at (B.) Birmingham, (H.) Hawkhurst, (Hy.) Hay, South Wales, (L.) London, (M.) Manchester, (T.) East Tisted, Hants, (Y.) York.

constant throughout the observations. The names of the stations are given, for shortness, in figs. 3 and 4, by their initials; and in the latter figure the observations have been so far adjusted to each other as to satisfy, by very slight changes in the majority of the observations, the condition of a parallel displacement of the meteor-tracks in the direction of a base-line joining the observers' stations.

The observed length of the path being, in general, most affected by this preliminary adjustment, a corresponding alteration of the observed duration of the meteor's flight was calculated, and entered in a Table as the "adopted duration," from the average of which, at the two stations, the velocities of twelve of the shooting-stars have been obtained. The time of visibility of

urst; (Ha.) Hay, Brecknocks and (Y.) York.

of Disappearance. ...rved. Alt.	Adopted. Azth. W. fr. S.	Adopted. Alt.	Length Observed Deg.	Se	...rent ...-point. δ.	Approximate place of radiant-point. Remarks.	Observer.
° 25	° 200	° 22	10	0·	+53°	γ Persei (radiant A_{10}).	W. H. Wood.
29	288	34	8	0·			R. P. Greg.
12	166	20	25	0·	65	*c* Camelopardi (radiant A_{10}).	W. H. Wood.
68	126	73	15	0·			R. P. Greg.
14	25	14	8	[illegible]	61	σ Cephei (radiant $N_{12,\,13}$).	W. H. Wood.
10	67	13	10	1·			A. S. Herschel.
46	133	49	22	...	36	*p* Persei (radiant A_{10}).	T. Crumplen.
42	180	42	31	...			F. Howlett.
54	126	56	30	1·	46	θ Persei (radiant A_{10}).	T. Crumplen.
46	195	43	19	...			F. Howlett.
31	......	......	15	Slo	......	....	T. Crumplen.
30	......	......	8	0·			A. S. Herschel.
70	316	73	34	...	58	χ Persei (radiant A_{10}).	T. Crumplen.
56	145	55	43	1·			A. S. Herschel.
26	270	25	12	...	44	ν Persei (radiant A_{10}).	T. Crumplen.
25	241	31	8	...			A. S. Herschel.
44	81	44	27	0·	58	δ Cassiopeiæ (radiant A_{10}).	A. S. Herschel.
71	325	73	46	...			F. Howlett.
38	204	43	16	...	38	ψ Persei (radiant A_{10}).	T. Crumplen.
24	169	26	25	1·			A. S. Herschel.
57	176	63	12	0·	45	κ Persei (radiant A_{10}).	A. S. Herschel.
43	122	44	29	...			F. Howlett.
22	152	28	17	0·	50	φ Persei (radiant A_{10}).	W. H. Wood.
38	67	29	17	1·			J. E. Clark.
23	222	26	6	0·	17	*g* Pegasi (radiant T_1).	W. H. Wood.
52	290	49	9	1·			J. E. Clark.
24	......	......	25	1·	......	....	A. S. Herschel.
......	......	......	......	...			T. W. Webb.
49	292	49	24	Sw	58	*d* Camelopardi (radiant A_{10}).	T. Crumplen.
75	211	65	9	0			A. S. Herschel.
29	225	30	6	0	+58	η Persei (radiant A_{10}).	W. H. Wood.
52	295	52	11	1			J. E. Clark.
			Ave... and d... of pa...		50°·7	Average velocity, and R. A. and N. decl. of the radiant-point of the "Perseïds" (omitting Nos. 3, 13).	

Table of Heights and Velocities of Shooting-stars in August 1870: observed in England, at (B.) Birmingham; (H.) Hawkhurst; (Ha.) Hay, Brecknockshire; (L.) Regent's Park, London; (M.) Manchester; (T.) East Tisted, Alton (Hants); and (Y.) York.

Number of References.	Date, August.	Place of observation.	Hour; approximate G. M. T.	Magnitude, as per *a* Lyræ.	Colour.	Streak and remarks.	Apparent place of First appearance, Observed α	δ	Adopted α	δ	Disappearance, Observed α	δ	Adopted α	δ
			h m s				°	°	°	°	°	°	°	°
1.	5	B.	11 21 0	2	Blue.	....	80	+62	75	+57	102	+62	90	+56
		M.	11 21 0	3½	Dull.	....	15	+27	10	27	13	20	0	17
2	6	B	11 11	3	Blue.	...	132	+63	129	64	162	44	149	55
		M	11 11	2	Dull		15	+82	15	+82	29	+72	278	+58
3		B	11 46	1	[illegible]		287	13	287	−13	285	21	285	−22
		H	12 45 0	= Lyr	White		252	+ 3	252	+ 3	247	6	248	− 3
4		L.	9 59 45	[illegible]			21	75	73	88	213	+53	213	+6
		[illegible]	[illegible]	1			5	55	54	67	11	81	11	81
5		T	[illegible]	= Lyr	Orange	Fine white streak	45	85	5	84	227	65	[illegible]	59
		T	[illegible]	Venus	Yellow		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	50	[illegible]
6		T	[illegible]	= Lyr	Orange	White sparks	24	46	273	[illegible]	16	31		
		H	[illegible]	1	Yellow		3	5	295	[illegible]	29	42		
7		T	[illegible]	2	[illegible]	[illegible]	341	55	[illegible]	[illegible]	[illegible]	32	314	38
		H	[illegible] 32	2	White	½ second	[illegible]	63	5	76	231	72	237	65
8		T	[illegible]	[illegible]			2	33	17	32	14	21	13	2
		H	[illegible] 34	1	Orange	2 seconds	[illegible]	42	28	42	32	35	32	47
9		H	[illegible] 47	3	White	1 second	265	52	274	58	247	25	248	28
		T	[illegible] 4 15	1	White		6	58	341	53	3 9	33	315	39
10		T	[illegible] 49 5	= Lyra	Orange	Very bright	53	48	53	48	51	64	5	72
		H	[illegible] 49	Capella	Orange	½ second*	114	[illegible]	73	56	[illegible]	57	144	64
11		H	[illegible] 52 5	3		1 second	227	58	22[illegible]	8	228	46	224	5
		T	[illegible] 52	1	White*		35	58	73	72	34	84	292	78
12		T	[illegible] 45	>1	White	White	158	65	184	73	171	5	19	58
		Y	[illegible] 29	1	White	2 seconds	279	31	274	25	277	17	272	17
13		B	11 56	1	White		59	5	33	52	75	45	73	48
		Y	12 [illegible]	[illegible]	Yellow	[illegible]	348	23	354	25	[illegible]	+16	4	27
14		H	12 2	> Venus	White	5 seconds*	291	18	263§	+ [illegible]	277	− 4		
		Ha.	12 2	= Mars			33[illegible]	[illegible]	325§	− [illegible]				
15	11	T	[illegible] 3	1½	Orange	White	2	44	35	+35	345	+28	343	25
		H	[illegible]	2	Yellow	[illegible]†	332	18	0	72	317	61	338	63
16	11	B	11 22	1	Yellow	‡	51	54	52	53	59	57	57	54
		Y	11 23	1	White	[illegible]	[illegible]	+34	2	+39	35[illegible]	+27	351	+27

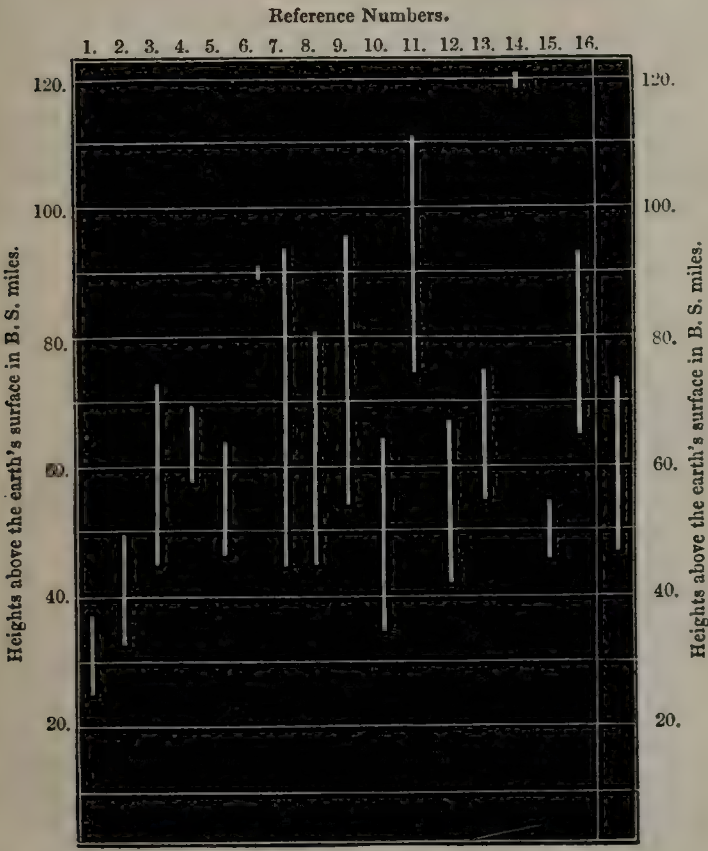
Number of References.	Place.	Apparent place of First appearance, Observed Azth. W. fr. S.	Alt.	Adopted Azth. W. fr. S.	Alt.	Disappearance, Observed Azth. W. fr. S.	Alt.	Adopted Azth. W. fr. S.	Alt.	Length of path and duration, Observed Deg.	Sec.	Adopted Deg.	Sec.
		°	°	°	°	°	°	°	°				
1.	B.	202	29	207	26	191	25	200	22	10	0.5	8	0.4
	M.	267	33	270	38	274	29	288	34	8	0.75	14	1.31
2	B	174	25	179	26	152	12	166	2	25	5	13	[illegible]
	M	192	53	192	53	175	68	126	73	15	5	3	1
3	B	26	23	26	22	25	14	25	14	8	[illegible]	9	[illegible]
	H	68	2	68	26	66	2	67	13	10	1.2	[illegible]	8.4
4	L.	158	52	182	50	123	46	133	49	22		32	
	[illegible]	214	29	214	36	180	42	180	42	31		24	
5	T	188	49	19	53	14	54	126	56	[illegible]	1.5	33	1.65
	T	219	33	211	36	21	46	195	43	19		[illegible]	
6	T	236	34	251§	32§	256	31			15	[illegible]		
	H	231	35	233§	34§	25[illegible]	3			8			
7	T	238	57	24[illegible]	65	34	7	316	73	34		33	
	H	22	46	169	55	251	56	145	55	43	1.2	31	[illegible]
8	T	244	31	258	3	278	20	27[illegible]	25	12		1	
	H	24	32	242	33	243	25	24[illegible]	31	8		3	
9	H	[illegible]	67	123	73	81	44	81	44	47	0.7	35	.91
	T	234	53	222	67	337	71	325	73	45		24	
10	T	224	27	224	27	231	38	2[illegible]4	43	16		24	
	H	133	32	2 8	25	158	24	169	20	25	1.5	34	2.04
11	H	341	41	2 9	52	156	57	170	6[illegible]	12	6	32	1.5[illegible]
	T	13	49	16[illegible]	54	114	43	122	44	29		21	
12	T	157	33	165	39	146	22	152	28	17	[illegible]	16	[illegible]
	Y	18	56	68	49	67	38	67	29	17	1	13	1.12
13	B	223	32	23	37	223	23	222	26	6	.5	14	1.75
	Y	3 4	[illegible]	3 5	54	2[illegible]8	52	29	49	9	1.5	9	1.5
14	H	41	4[illegible]	4[illegible]§	5[illegible]§	47	24		...	25	1.5		
	Ha.	33[illegible]	47	35 [illegible]§	325								
15	T	255	43	275	57	258	43	292	49	24	Swift	1[illegible]	...
	H	211	67	2 9	57	215	75	211	65	9	[illegible]	8	.53
16	B	225	35	225	34	224	29	225	3	6	.5	4	.33
	Y	278	52	269	54	295	52	295	52	11	1.0	14	1.27

Number of References.	Adopted average duration.	Height in B. S. miles at Appearance, Miles	Long.	N. Lat.	Disappearance, Miles	Long.	N. Lat.	Length of path, B. S. miles.	Velocity in B. S. miles per second.	Apparent radiant point α	δ	Approximate place of radiant point. Remarks.	Observer.
	sec.												
1.	0.855	37	1 1 W	53 27	25	1 25 W	53 2	22	20	43	+ 3	Persei (radiant A..)	W. H. Wood
													R. P. Greg
2	0.63	5[illegible]	2 58 W	54 [illegible]	33	2 24 W	53 3[illegible]	39	62	73	65	[illegible] Cas[illegible]	W. H. Wood
												radiant A[illegible]	R. P. Greg
3	0.84	74	2 59 W	49 56	45	3 2 W	5[illegible]	28	33	322	61	σ Cephei	W. H. Wood
												radiant N[illegible]	A. S. Herschel
4		77	[illegible] W	52 24	58	1 3 W	52 2	50		38	30	ρ Persei	T. Crumplen
												radiant A[illegible]	F. Howlett
5	1.65	6	[illegible] 4 E	52 14	47	[illegible] 5 W	51 52	50	3[illegible]	40	46	θ Persei	T. Crumplen
												radiant A	F. Howlett
6	[illegible] 7	9	2 21 E	5[illegible] 33	centre of path								T. Crumplen
													A. S. Herschel
7	.8[illegible]	[illegible]	1 4 E	[illegible]	45	[illegible]	[illegible] 24	7[illegible]	58	[illegible]	58	γ Persei	T. Crumplen
												(radiant A[illegible]	A. S. Herschel
8		82	3 7 E	51 5[illegible]	45	2 [illegible]1	51 [illegible]	62		22	44	ι Persei	T. Crumplen
												(radiant A[illegible])	A. S. Herschel
9	.91	96	[illegible] W	51 16	54	4[illegible] W	5[illegible] 53	57	63	20	58	ζ Cassiopeiæ	A. S. Herschel
												radiant A[illegible]	F. Howlett
10	2.04	65	1 6 E	53 1	33	[illegible] 2 W	51 58	93	40	52	38	ψ Persei	T. Crumplen
												(radiant A[illegible])	A. S. Herschel
11	1.5[illegible]	111	[illegible] 1 E	52 14	74	1 6 W	5[illegible] 38	73	49	44	45	κ Persei	A. S. Herschel
												(radiant A[illegible])	F. Howlett
12	0.915	66	2 25 W	53 39	42	2 45 W	53 31	3[illegible]	33	2	5	[illegible] Persei	W. H. Wood
												radiant A[illegible]	J. E. Clark
13	1.625	76	1 W	53 2	54	6 W	53 4[illegible]	28	17	33[illegible]	17	η Persei	W. H. Wood
												(radiant I[illegible])	J. E. Clark
14		1 2[illegible]	2 15 E	49 25	centre of path								A. S. Herschel
													J. W. Webb
15	0.53	55	[illegible] 56 E	51 27	47	[illegible] 44 E	51 [illegible]	17	3[illegible]	6[illegible]	54	[illegible] Cas[illegible]	T. Crumplen
												radiant A	A. S. Herschel
16	0.80	95	0 27 E.	53 54	64	0 2 W.	53 36	47	59	41	+56	η Persei	W. H. Wood
												(radiant A_{10}).	J. E. Clark
Average height at appearance and disappearance and length of path in British Statute Miles		74.1 miles			47.6 miles			48.0 miles	48.8 miles per sec.	4[illegible]	5[illegible]	Average velocity and R. A. and N. decl. of the radiant point of the Perseids [illegible]	

* [illegible] brightest part of its course the meteor and its streak were seen through thin clouds.
† [illegible] of the end of the meteor's course. Path slightly curved.
‡ The meteor [illegible] collapsed suddenly at its greatest brightness.
§ [illegible] ‖ [illegible] observed at Hay.

the August meteors in the present year was rendered almost momentary, apparently by the great brightness of the moonlight; while the absence of

Fig. 5.



Heights at first appearance and disappearance of sixteen shooting-stars observed in England, August 5th–11th, 1870. (Nos. 6 and 14 are heights at centres of the real paths.)

small stars of reference near the meteor's course, necessitating distant alignments of the apparent paths with the larger stars, prevented the average length of path of the observed meteor-tracks from being at the same time much diminished. Both the length of path and the velocity * are on this account rather larger than those of twenty shooting-stars which were similarly observed in August 1863 (forty-seven miles, and thirty-four miles per second. See Report for 1863, pp. 327–330). Among the meteors included in the list, Nos. 3 and 13 belong to different meteoric showers (N_{12}, $_{13}$, and T_1) from that of the regular Perseids; and the latter meteor presents a velocity considerably below the average of all the remaining velocities of the list. Although the disturbing influence of the moon's light appears to have exaggerated and to have rendered somewhat uncertain the velocities obtained on this occasion, the velocities of these two meteors are omitted from the average velocity of the Perseids or meteors of the August shower, of which

* Forty-eight miles, and forty-six miles per second (average of the Perseids). Velocities of the meteors Nos. 3 13, thirty-nine, and seventeen miles per second.

the average position of the radiant-point was found to be very near the star θ Persei. The heights of the first and last points of the meteors' tracks and the average of those heights are shown in fig. 5, by a graphic projection readily exhibiting to the eye the height in the atmosphere at which the shooting-stars of the August meteoric shower became ignited, and were extinguished, during the appearance of the phenomenon in the present year.

The additional correspondences of the Greenwich observations with those meteor-tracks whose heights have already been determined, and with other shooting-stars recorded at the different stations (of which a summary will be given in the next Report), are at present undergoing calculation; and they may be expected, on concluding the results of their investigation, to afford interesting materials for comparison with the observed paths of the shooting-stars recorded in the present list.

1870, August 15th, 9^h P.M., G. M. T., Scotland and Ireland. The position of the very luminous streak which this meteor left was over the southern part of the Hebrides, and the Atlantic Ocean north of Ireland; but at what distance from the land, and at what height in the atmosphere, it would require a comparison of other descriptions of its course to ascertain. As the sun was fully 12° or 13° below the north-west horizon of the region indicated, it would still be half that depth, or about 6°, below the horizon of the meteor-streak, if its elevation was only as great as the height at which the largest August meteors commonly develope a very long enduring, phosphorescent streak, about fifty-five miles above the level of the sea.

1870, August 20th, 9^h 24^m P.M., G. M. T., London, Cambridge, and Oxford. The apparent courses of the meteor, as described at Clapham Park, London, and at Linton, Cambridge, are almost identical, so as to afford no definite conclusion of the meteor's height. At Wandsworth, near Clapham, Mr. H. W. Jackson saw the meteor commence about the trapezium (β, γ) of the Little Bear, and disappear halfway between Capella and Algol, while at Linton it disappeared almost over α Cassiopeiæ. With the distance of forty-five miles between the latter places, and a parallax of 32° for the last point of its visible course, these observations give the place of disappearance at a point about twenty-one miles over Bury St. Edmunds. As this place is within a few degrees of the altitude and direction at which its disappearance was observed at Combe, near Woodstock, in Oxfordshire, it may be accepted, probably, as very near to the true position of the point at which the meteor disappeared.

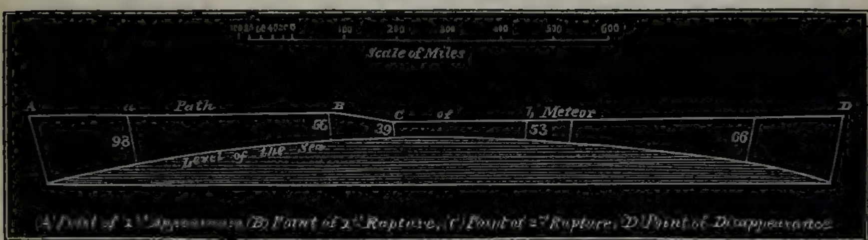
The exact place of the meteor's first appearance cannot be absolutely ascertained. But supposing its apparent course at Linton to have passed about 20° north of the zenith, and to have descended "almost perpendicularly" (with an inclination of about 20° from the north of vertical), as it was perceived to fall towards the eastern horizon at Woodstock by Mr. J. Abrahall, its real course, preserving the apparent path which it appeared to have at Wandsworth, began from the direction of a radiant-point between the head of Boötes and Corona Borealis, at about R. A. 230°, N. Decl. 35°. At its passage due north of London the height of the meteor, on this assumption of its initial direction, was about fifty-three miles above a point between Huntingdon and Cambridge, descending towards its point of extinction from an inclination of 45° above the due west horizon. A more complete knowledge of this extremely brilliant meteor's real course can only be obtained, to corroborate, or correct, the present provisional determation, if notices of its appearance were obtained by observers at other places, who would communicate to the Committee a description of their observations for this purpose.

II. Large Meteors.

1822, October 16th, evening, London. The following extract of a note in Sir John Herschel's MS. Journal refers apparently to a large fireball of which no mention is found in Mr. Greg's and other Catalogues of the appearances of unusually brilliant meteors.—"1822, October 16th, Wednesday. This evening, walking home from the Haymarket to Downing-street, being at the Horse Guards at $8^h\ 37^m$ P.M., saw a great light, like the moon breaking out among the clouds, and a fiery appearance like the bursting of a rocket, not globular, but in ill-defined masses. Direction exactly before me, as I walked towards Westminster from Charing Cross. Altitude about 15° or 16°; sky overcast; a mizzling rain and fog. No explosion heard; ? its nature, if meteoric?—(J. F. W. H.)"

1860, July 20th, $9^h\ 34^m\ 33^s$ to $9^h\ 36^m\ 24^s$ P.M. (Washington mean time), United States, America. An exhaustive investigation of the path of this large meteor, from a comparison of observations at more than 200 places in the United States and the adjacent parts of Canada, by Dr. J. H. Coffin, is contained in the 'Smithsonian Contributions to Knowledge,' vol. xvi. for 1870. The meteor was first reported to have been seen moving eastward from a point nearly over the western shore of Lake Michigan, westward from which it might perhaps have been observed had not a cloudy state of the sky prevailed at the time throughout that region. Along the entire remaining portion of its visible track of nearly, or quite, 1300 miles, it was watched by numerous observers until it disappeared quite out at sea in a south-easterly direction from the island of Nantucket. It was first well observed at Flint, Michigan, between the great Lake of that State and Lake Huron, pursuing from that place and from the remaining points of view along its line of flight an apparently undulating or ricochet motion until it faded from sight, without breaking into fragments, towards the eastern horizon. It was accompanied throughout the greater portion of its path by a brilliant train, and followed at a distance of about 1° or 2° by a smaller fireball of the same dazzling white colour as the head; while near the end of its course sparks or flakes of red and pink colour were cast off by the nucleus in considerable numbers. The length of time that it was visible at one station, depending upon the length of the arc which was observed, varied from half (or rather less than half) a minute to about two minutes; and the whole time occupied by the

Fig. 6.



meteor in its visible track was about three minutes. At the points B, C (see fig. 6), in long. west from Greenwich about 77° and 74°, and especially at the latter point, distinct ruptures of the meteor were observed, corresponding to which the real height and direction of its course underwent a sensible alteration. The actual height of the meteor when it was first well observed in long. 85½° west from Greenwich (at *a*, fig. 6), at Flint,

Michigan, was ninety-eight miles above the earth, and the first inflection of its course, nearly over Dansville, New York, took place at a height of fifty-six miles, and the second, nearly over New York, at thirty-nine miles above the sea. The last place where the meteor was well observed was at Germanstown, Pennsylvania, and the meteor was then fifty-three miles above the level of the sea, in long. about $68\frac{1}{2}°$ west from Greenwich (at *b*, fig. 6). Finally, at Harrisburgh, Pennsylvania, it was still visible in the east, in longitude about 60° west from Greenwich; and its height was then rapidly increasing, and was again upwards of sixty miles above the sea-level.

The meteor pursued its course with a velocity, relative to the earth, of about nine and three-quarter miles per second, experiencing throughout its aërial track a small but scarcely appreciable resistance from the atmosphere. With a relative velocity somewhat less than this it entered the sphere of the earth's dominant attraction from the direction of a point in R. A. 147° 41′, N. Decl. 3° 8′, and it was deflected before escaping from the disturbing influence of gravity towards the earth fully 35° from its original direction. The circumstance of its slow velocity relatively to the earth introduces complexities in determining the real orbit of the meteor round the sun, which it would yet be interesting, from the elaborate calculations to which the observations were submitted, and from the unusual accuracy with which the elements of this great meteor's path have accordingly become known, to ascertain with every possible degree of approximation to the most probable result.

The long course and duration of the flight of the large meteor doubly observed on the 12th of December, 1869 (see the First Appendix), furnishes a good example during the past year of a shooting-star belonging to a periodical meteor-stream grazing for a long distance, without being consumed, the summit of the earth's atmosphere, and suggests as a favourable means of ascertaining their velocity, the propriety of observing their parallax when the radiant-point of a meteoric shower is scarcely risen, or presents itself, as in the case of the great meteor of July 1860, at only a few degrees of altitude above the observer's visible horizon.

1869, May 20th, a few minutes after 11^{h} P.M. (local time), United States. The meteor, which appeared brighter than the full moon, was seen at many places in the United States (*vide* Amer. Journal of Science, July 1869) remaining visible for about five seconds, drawing behind it a very brilliant tail of sparks, and finally exploding and bursting into fragments, apparently with a loud report. From observations at New York, Poughkeepsie, Newhaven, and Hartford, U.S., of its apparent path, Prof. E. Loomis has determined with considerable precision the length of the meteor's real path and its real elevation. The meteor moved nearly horizontally at a height of fifty miles above the earth's surface, disappearing, after a visible course of about 200 miles, vertically over a point on the Atlantic Ocean somewhat north and east of Boston. The real velocity of its motion, assuming its time of flight to have been five seconds, was about forty miles per second. About three minutes after the passage of the meteor a terrific noise was heard in the neighbourhood of New York, which shook windows and the doors of houses like an earthquake. As Prof. Loomis shows that the meteor was at the time of its explosion 170 miles distant from places where the unusual sounds were heard so soon after its disappearance, it is supposed that they must accordingly be ascribed to some other cause than this large meteor, the sound of whose report would occupy ten minutes in reaching them, with the ordinary velocity of sound in common air.

1869, August 7th and 24th, evening, United States. The following de-

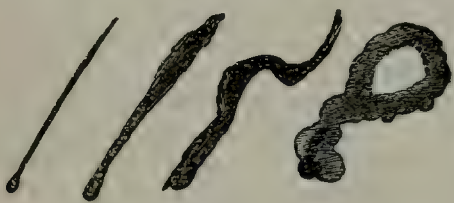
scription of bright meteors seen in the United States on the 7th and 24th of August, 1869, was communicated by Mr. B. V. Marsh to the Secretary of the Committee, Mr. Herschel, soon after the time of their appearance. The occurrence in the present year of a very brilliant meteor-streak observed in Scotland at sunset on the 6th of August, 1870, appears to corroborate the opinion of Mr. Marsh, that a meteor-shower from some western radiant-point has prevailed on the 6th and 7th of August of the two last years, of which the meteors were chiefly visible soon after sunset. A second brilliant meteor-streak was observed in Scotland soon after sunset of the evening of the 15th of August last (see Appendix I.; 1869, August 15th), which appeared to one observer to be self-luminous, and to others to be illuminated by the sun's rays in the manner in which Mr. Marsh observes that the streak seen in America on the 24th of August, 1869, was evidently rendered more than ordinarily brilliant.

"On the 7th of August, a little while after sunset, several were seen descending almost vertically in the west and north-west, being very conspicuous even in the strong light of the western twilight.

"One which I saw at 7^{h} 49^{m} started about 18° high and disappeared at about 6°; fell almost vertically, but inclined a little to the right.

"'The Press' noticed one at 7^{h} 55^{m}, the cloud from which remained visible ten minutes.

"August 24th, Mr. J. S. Hilles, of the Reading Railroad, saw one in the north-west, just as the upper limb of the sun disappeared: a very brilliant fireball inclining considerably to the right [see the figure] as it descended, and leaving behind it a perfectly straight streak of brilliant white light slightly enlarged at its lower end, and having at that part a nebulous undefined appearance; whole length say 15° or 20°. This assumed successively the following forms:—



During this time it had floated westward until it was nearly over the setting sun, and was beautifully lighted 'with the rose hues of sunset, while its upper part assumed a strikingly silvery appearance.'

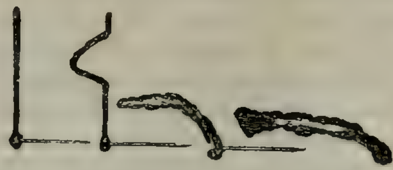
"Mr. Hilles did not look at his watch, but his impression at the time was that it remained visible half an hour; but he thinks that this may be an over-estimate.

"At 7^{h} 25^{m} the same evening (August 24th) another appeared which attracted very general attention.

"One of my neighbours, after watching it about five minutes, called me out. The luminous cloud was then very conspicuous, its base about 15° north of west, altitude about 13°. The meteor had fallen almost vertically, and at that point had appeared to explode. It vanished so quickly that most persons saw only the flash, but several say they saw the meteor itself before the explosion.

"Its path was marked by a brilliant line of light, which soon widened so as to appear as a narrow strip of cloud, say 3° or 4° long and $\frac{1}{4}$° wide, having at its lower extremity a much brighter part resembling the nucleus of a

comet. This luminous cloud was visible fully ten minutes; the changes it underwent are roughly sketched below. Both the top and bottom of the



column seemed to remain almost stationary, whilst a considerable portion of the upper half drifted westward, as if carried by an east wind.

"From the 'nucleus' there was also a bright line extending horizontally to the right, 2° or 3° long, as indicated by the *red* line. This seems to have been almost as bright as the principal column, but much narrower, and therefore not so generally noticed.

"My friend Jos. Walton watched it some minutes with an opera-glass, and says it was as distinct as the other.

"This must have been thrown off instantaneously by the explosion.

"The luminous cloud, and especially the 'nucleus,' was so bright that at Atlantic City, sixty miles east of this place, it was by some mistaken at first for a 'fire balloon.'

"The explosion was more than 200 miles west of Philadelphia, at a height of forty-five or fifty miles.

"The meteor and cloud (or more generally a flash of light and the cloud only) were observed at Yonkers and Harlem, near New York; at Atlantic City, and Trenton, in New Jersey; Wilmington, Delaware; and at Philadelphia, Lancaster, Columbia, in Pennsylvania.

"At Clarion, 250 miles west of Philadelphia (or north of west, rather), it appeared in the south-east, and disappeared in the north-west; and it was followed by a sound resembling thunder, or the rolling of a heavy body over a floor. I do not find that it was seen at all at any point further west. Here it appeared at forty minutes after sunset. At Clarion the sun had set only about twenty-five minutes before; the general twilight was therefore much stronger. This circumstance, coupled with the fact that the meteor itself lasted only a second or two, not long enough for persons to look overhead and see it, probably explains the fact that it does not seem to have been seen generally in the region where it was vertical.

"At places in Ohio so far west that the meteor would appear in the east so low as to be within the view of persons walking with the head in its ordinary position it might be expected to be seen, but in this case the interval from sunset is further reduced to about ten minutes, which is probably more than sufficient to counterbalance the effect of the darker background in looking towards the east.

"But a still stronger reason probably is that the light from this cloud was principally sunlight, and that therefore the cloud would, like any other cloud, be more brilliant when in the west than in the east, the effects of refraction exceeding those of reflection.

"This circumstance probably has something to do with the fact that *all* of the above-mentioned meteors were seen in the *western* sky, and no corresponding ones in the east.

"As none have been observed later in the evening, when twilight was gone, it would seem as if these meteors belonged to a group that were essentially *daylight* meteors.

"When this meteor appeared, the sun was just setting 10° west of our longitude, and an object only fifteen miles high over Clarion County would be in the sunshine. This meteoric cloud was not less than forty miles high, and *must* therefore have been illuminated in this way; as no other instance has come to my notice I was much interested in it, but when I commenced this letter I had no idea of troubling you with so long a story.

"Yours respectfully,

"*To A. S. Herschel, Esq.*" "BENJ. V. MARSH."

1869, September 8th, 7^h P.M. (local time), Germany, France, Switzerland, and Italy. A magnificent fireball was seen in the south-west of Europe, over an extent of fully 20° in latitude and longitude, on the evening of the 8th of September. The descriptions of its appearance at Strasbourg, Pisa, Arezzo, and Genoa are contained in the 'Meteorological Bulletin' of the Urbino Observatory for August 1869; and at the Piedmontese stations, and at Milan, where it was seen by Prof. Schiaparelli, at Ancona, Bologna, Civita Vecchia, and numerous other places in Italy, in the 'Meteorological Bulletins' of the Moncalieri, and Royal College of Rome Observatories for September, 1869. According to Mr. C. A. Kesselmeyer the meteor approached the southern part of Europe from Prussia, and after crossing the Rhenish provinces between Bohemia, Bavaria, and France, it crossed the Alps of Switzerland and Savoy, being seen near the Lake of Constance, at Lucerne and Geneva, and thence pursued its course to Italy, where it was seen at Marseilles, Civita Vecchia, and Naples, proceeding from north-east towards south-west across the Mediterranean sea. The numerous observations of its course obtained in different countries of Europe will afford ample materials for a very rigorous calculation of its path, not less instructive than the passage of the great meteor over America on the 20th of July, 1860, and may at some future time be expected, like the path of that meteor, to furnish tolerably exact elements of a meteoric orbit round the sun. In the length of its path, the date and hour, and the brilliancy of its appearance it closely resembles the large fireball seen in Italy, Switzerland, and France on the evening of the 5th of September 1868 (Report for 1869, p. 272).

1870, August 6th and 15th, about $10^h\ 6^m$ and 9^h P.M., Scotland and Ireland. A description and drawing of the streaks of these large meteors were received from Mr. T. W. Backhouse; and others are contained in the 'Astronomical Register,' and in 'Nature' of September 1st, 1869. The relative abundance of shooting-stars on the night of the 6th of August, 1870, described in the next Appendix, and the occurrence of similar meteors in America last year on the evenings of the 7th and 24th of August, appear to indicate that each of these large meteors was connected with a periodical shower of shooting-stars in August, differing to some extent in the time of maximum from the annual epoch of the 10th, and of which the position of the radiant-point, perhaps more westerly, has not yet been exactly ascertained.

III. AËROLITES.

Motta dei Conti, Casale, Piedmont, 1868, February 29th, 11^h A.M. (Report 1868, p. 390.)

The stone is exceedingly crystalline, light-coloured, fine-grained, and rough in fracture, having a density 3·43. Possessing these characters in common with the meteorites of Lucé, Manerkirchen, Politz, Sanguis, St. Etienne, and several others, M. Meunier designates this species of

meteoric rock by the name of *Lucéite*. Like a similar distinct minera *Montréjite*, of which the meteorite of Montréjeau is entirely composed, it i sometimes found imbedded in small portions in the darker mass of othe aërolites. It it so found in the meteorites of St. Mesmin, of the Asturia and of Assam; while its analogue, Montréjite, is found similarly distribute in the meteorites of Canellas, Guttersloh, and Baffe. The recognition of suc a structure materially assists the classification of meteorites under commo types, and suggests considerations regarding the process and sources fro which they are derived. ("On the Meteorite of Motta dei Comti," b Stanislas Meunier, 'Bulletin of the Moncalieri Observatory' for March 1870.)

From a collection of thirteen examples of the oolitic class of aërolites i the Mineralogical Museum at Paris, M. Meunier obtains the followin numbers of aërolitic falls of this peculiar class in the several months of th year, showing that meteorites of the same type are not confined to singl orbits or to single rings of meteoric materials encompassing the sun, but ar found in the same regions of space with meteorites of other types. (Lette from M. Meunier to Mr. R. P. Greg.)

Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total number of aërolites.
2	1	0	1	2	1	0	1	1	1	1	2	13

Lodran, Moultan, India, 1868, October 1st.

Specimens of this aërolite in the Mineralogical Museum of Vienna wer analyzed by Dr. G. Tschermak, the results of whose chemical investigations together with a notice of a specimen of meteoric iron from the desert o Atacama, presented to the Museum, is contained in the 'Proceedings of th Vienna Imperial Academy of Sciences' for 1870, April 7th.

Krähenberg, near Zweibrücken, Bavaria, 1869, May 5th, 6^h 30^m P.M. (Report 1869, p. 278.)

In the 'Proceedings of the Vienna Imperial Academy' for 1870, April 28th M. von Haidinger produces fresh proofs of the rotation of meteorites on thei axes, and of their orientation, or presenting front and rear faces to th atmosphere during the luminous portions of their descent to the earth, an some remarks on the original formation of siderites in veins of meteori rocks, as illustrated by the meteorite of Krähenberg, and by the large ring-shaped siderite of Ainsa-Tucson preserved in the collection of the Smithsonia Institute in America. M. von Haidinger in the same paper explains th appearance of meteoric iron-masses in pairs, first pointed out by Professo W. H. Miller of Cambridge, in the siderites of Agram, Braunau, and Cran-bourne, Australia, and in the description of the historical iron-masses whic fell at Troy, by supposing that the fusion of their surface by the fireball which might first perforate and produce a ring-shaped meteorite, might i continued further divide the ring at one point and cause it to break a another by the resistance of the air. Attention is also drawn to th occurrence and apparent frequency of veins in the geology of meteoric rocks first pointed out in his note of 1868, October 8th (see these Reports for 1869

p. 300), and again more prominently regarded by M. Meunier, in a series of able articles, as explaining the condition of their primitive existence in and original separation from a parent planet*.

Parvatypore, Vizagapatam, Madras, India, 1869 (?), December 23rd.

The following account of the fall of a meteoric iron in India is copied from the 'Homeward Mail' of 1870, March 14th.—"A phenomenon of the meteoric kind is reported by the 'Madras Athenæum' as follows:—'An aërolite weighing about ten pounds fell in the neighbourhood of Parvatypore in the Vizagapatam district, on Sunday, December 23 [so in the 'Homeward Mail;' ? if Sunday, Dec. 26th, 1869]. We have been favoured with some particulars regarding this occurrence. The substance of which this aërolite consists is apparently iron in a very pure state, without any mixture of other mineral substances or impurities. The mass is shaped and marked, and even on one side (that evidently which came in contact with the earth) polished in a manner naturally to be expected under the circumstances, namely a mass of iron in the malleable condition which that metal takes when in a state of fusion coming into contact with earth softened by moisture, and with a force sufficient to penetrate to a depth of 2 feet. We are told that the noise caused by the aërolite in passing through the air in its fall was very startling, and to the people in the immediate neighbourhood alarming. Its luminous splendour is described as equal to that of the moon, and it is said to have culminated with an explosion of great brilliancy. It was seen and heard for many miles, as it fell in a direction from north to south.'"

Mourzouk, Fezzan, 1869, December 25th, evening.

A large globe of fire fell to the earth with an explosive sound, in sight of a group of Arabs, near the capital of Fezzan, and imbedded itself in the ground. The meteorite, which weighs 6000 lbs., is destined to be preserved in the public Museum of Constantinople. M. von Haidinger, of Vienna, and Mr. R. H. Scott, in London, have presented to the geological societies of their respective countries a description of the circumstances which attended its fall.

Periodicity of Detonating and Non-detonating Fireballs, and of Aërolites.—From a collection of the most recent Catalogues of large meteors and aërolites, Mr. Greg has revised the Tables appended to his first Catalogue of such appearances printed in the volume of these Reports for 1860. The following more complete and carefully reconstructed Tables exhibit at a glance the particular days of the year on which large meteors have thus appeared in greatest numbers, the months or seasons of the year in which aërolites are most common, and in which they have been especially observed in each year for the last period of more than half a century. The question of the periodicity or non-periodicity of those rare occurrences cannot fail to arrive at an ultimate solution by systematic arrangement and classification, of which the Tables now reproduced, and brought up to the latest dates of his extended Catalogue by Mr. Greg, are a valuable and well-timed contribution.

* 'Cosmos' for 1869, November 20th, 27th, and December 4th; and 1870, January 1st, "On the Siderite of Deesa [or of Copiapo (M. von Haidinger, *ibid.*)], the existence of eruptive meteoric rocks, and *the relative ages* of meteorites," by Stanislas Meunier.—On Mr. Meunier's views regarding the relative ages of a supposed iron-period and stone-period in the history of meteoric falls, see a lucid article by Professor N. S. Maskelyne, in 'Nature' for 1870, June 2nd.

Table showing Number of Large Bodies, or Meteors (non-detonating), recorded A.D. 1500–1870 for each day of the month.

Day of month.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1.	5	4	7	3	1	6	1	5	4	6	9	3
2.	9	7	4	3	5	5	3	7	9	3	9	7
3.	4	7	5	4	2	1	2	13	3	8	5	6
4.	6	3	2	5	7	2	4	5	8	7	7	4
5.	0	2	3	1	1	1	6	8	5	4	4	5
6.	5	7	7	5	3	8	2	6	8	6	10	3
7.	5	11	3	0	4	3	0	8	10	6	5	6
8.	4	4	5	4	2	3	3	9	4	2	10	13
9.	6	3	3	1	2	4	3	16	2	4	12	10
10.	6	7	4	3	4	3	2	23	8	8	4	6
11.	7	4	1	8	4	3	9	8	5	3	13	19
12.	5	2	4	8	4	7	8	15	3	4	11	13
13.	5	3	4	4	2	5	7	8	5	7	23	8
14.	1	2	2	7	1	3	3	6	1	5	15	5
15.	6	4	5	2	9	2	5	8	4	10	10	4
16.	4	1	0	2	5	5	5	9	5	6	10	5
17.	1	6	4	5	5	4	7	3	1	7	6	5
18.	3	6	3	6	6	4	3	6	3	6	6	7
19.	6	5	5	7	4	5	3	7	6	5	15	3
20.	8	4	4	2	3	2	7	8	8	8	6	2
21.	9	5	1	2	3	2	4	2	2	4	2	13
22.	5	6	2	0	4	4	2	8	8	6	4	4
23.	6	5	4	0	2	4	5	7	1	8	7	2
24.	6	2	4	5	3	2	5	2	4	10	2	2
25.	3	1	3	2	2	1	3	5	6	5	1	6
26.	8	3	3	1	3	1	3	8	0	6	5	0
27.	5	2	4	4	2	4	4	1	6	6	7	5
28.	5	2	5	4	2	4	3	4	6	5	9	5
29.	4	1	4	5	4	4	12	6	2	6	8	5
30.	6	0	5	4	2	5	7	6	7	4	5	7
31.	5	0	4	0	7	0	4	3	0	4	0	4
Totals	158	119	114	107	108	107	135	230	144	179	240	187

Table showing number of Stonefalls and Detonating Meteors for each month, from A.D. 1800 to 1870.

Year A.D.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Month unknown.	Yearly totals.
1869.	2	......	......	......	2	......	3	1	......	1	......	1	......	10
1868.	1	1	1	......	......	......	......	......	1	2	2	......	1	9
1867.	......	......	......	......	......	2	......	......	......	......	......	......	......	2
1866.	½	1	1	......	2	2	......	......	......	......	1	3	......	10½
1865.	1	1	......	......	1	1	1	4	2	1	1	2	......	15
1864.	......	......	......	1	1	1	......	1	2	......	2	1	......	9
1863.	1	......	3	......	......	1	......	2	......	......	1	5	......	13
1862.	......	......	......	......	......	1	½	1	......	1	3	......	......	6½
1861.	1	......	1	......	2	1	½	......	......	......	1	2½	......	9
1860.	1	1	2	......	1	1½	3	2	......	......	1	1	......	13½
1859.	......	1	1	......	......	......	½	2	2	½	3	......	......	10
1858.	1	......	......	......	1	......	......	½	1½	......	......	2	......	6
1857.	......	2	1	2	......	......	......	½	......	2	1	2	......	10½
1856.	......	2½	......	½	......	......	1	......	1	1	1	......	......	7
1855.	......	......	......	......	3	1	......	1	......	......	......	......	......	5

Table (*continued*).

Year A.D.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Month unknown.	Yearly totals.
1854.			1				1½		1		1			4½
1853.		1	1½									2		4½
1852.	1								1	3		1½	1½	8
1851.	1	1		1			1				1	½		5½
1850.	1½	1		½	1	4	½		½		1	1		11
1849.			1			1		2		1	3			8
1848.		1			1		½					1		3½
1847.		1	1				1							3
1846.					1	1	1		½	1	1	1	½	7
1845.	1½								1			1		3½
1844.	1	½		1			1		1	2½	1			8
1843.			1			1	1	1	1	2	1	1		9
1842.				1		2	1	½		1	2	1		8½
1841.			3			1	1				2	1		8
1840.	1				2	1	1			1				6
1839.		1									2			3
1838.	1			1		1				1				4
1837.	2			½	1		1	1						5½
1836.	2	1						1			1½	1	½	7
1835.	1½		½				2	1			1			6
1834.			1			1					½	2	½	5
1833.			1				½				3	1		5½
1832.			1											1
1831.	1						1½	½	1					4
1830.		1			1									2
1829.					1		½	1	1½	1	½			5½
1828.					1	1								2
1827.		1			2			1½	1	1				6½
1826.		1		½	1			1	1				½	5
1825.	½	1			1		1		1					4½
1824.	1	1						½		1				3½
1823.								1						1
1822.			1			2½		1½	2½		1			8½
1821.			½			1						1		2½
1820.				½	1		1	1			1½			5
1819.				1	1	1	1	1		1	1			7
1818.		2		1		1		1		1				6
1817.												1		1
1816.			1				½	1½						3
1815.		1			1					1			½	3½
1814.		1					1		1		1			4
1813.	1		2					½	1½			1		6
1812.				2				1					½	3½
1811.			1				1				½			2½
1810.	1			½			1	1			2			5½
1809.						1								1
1808.				1	1				1				1	4
1807.			1									1		2
1806.			1		1				½					2½
1805.		1	1			1					1			4
1804.			1	1										2
1803.				1	1		1			1		1		5
1802.									½	1			1	2½
1801.													1	1
1800.				2										2
Monthly totals...	26½	27	31½	19	32	33	33	35½	28	29	46½	39½	8½	389

A Table showing the number of *Stonefalls* (A), *Detonating Meteors* (B), and *very large Fireballs* (C), from A.D. 1500 to 1870, compiled from the late Catalogues in the British Association Reports.

Day of month.	January.			February.			March.			April.			May.			June.		
Classes...	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.
1.	1	1	5	...	...	2	1	2	2	3	2	2	1	...	1	...	...	4
2.	...	3½	5	1	...	5	1	...	3	...	...	1	...	...	3	2	1	2
3.	...	...	3	1	2	2	...	...	4	...	...	2	...	...	1	2	3	1
4.	2	...	3	...	...	2	...	1	2	...	...	5	...	1	6	1½	1	2
5.	...	1	...	...	...	2	½	...	1	2	½	1	1	1½	1	1	1	...
6.	...	...	3	...	1	4	2½	...	4	...	...	2	...	...	3	1	2	5
7.	...	...	4	...	1	4	...	1	2	...	...	...	...	...	1	2	...	4
8.	...	1½	4	...	1	...	1½	...	4	...	1	2	2	...	1	...	...	1
9.	1½	1	6	...	½	1	...	1	3	1	1	1	2	1½	...	4	...	2
10.	1½	1	4	2	1	6	...	1	2	2½	...	2	...	1	3	...	1	2
11.	...	...	2	...	2	3	...	1	2	1	...	4	1	½	3	...	2	2
12.	...	2	2	...	...	1	2½	1	1	1	1	5	1½	...	3	3	1	2
13.	1	...	3	1	...	2	1	...	3	1	...	3	1½	1	...	1	...	2
14.	...	...	...	1	...	1	1	...	2	2½	...	3	2	1	1	1	...	1
15.	2	...	2	2	1	1	1	1	3	...	...	2	...	½	4	1	...	1
16.	2	2	3	1	1	2	1	...	1	...	...	1	...	...	1	3	1	1
17.	...	1	...	...	1	3	1	1	2	2	...	3	4½	...	...	1	...	4
18.	1	...	1	3	1	2	...	1	2	1	...	3	1	...	3	...	...	2
19.	1	...	2	1	1	2	1	2½	2	1	...	2	4	...	3	1	...	5
20.	...	½	5	...	½	1	1	...	2	½	...	...	1	...	1	2	1	2
21.	...	...	6	...	1	2	...	2	...	...	...	2	1	2	1	...	...	1
22.	...	½	1	...	2	4	1	...	2	...	...	1	2	½	1	1	1	3
23.	1	½	4	...	1	4	...	1	2	...	...	...	1	...	1	1	...	2
24.	...	...	3	...	...	1	1	...	2	...	...	2	...	...	3	...	...	1
25.	...	...	2	1	2	1	2	...	1	...	...	1	...	...	1	...	1	...
26.	...	...	3	...	...	2	1	...	2	2	...	1	1	...	2	1	...	1
27.	...	2	4	1	...	...	...	...	2	...	...	2	1	...	2	...	...	..
28.	1	...	3	1	...	1	2	...	3	½	...	2	2	...	2	...	...	2
29.	2	...	1	1	...	1	...	...	4	1	...	4	1	...	1	...	1	3
30.	1	...	3	...	...	...	1	...	4	1	½	4	1	...	1	...	...	...
31.	1	...	4	...	...	...	...	1	2	...	...	1	...	...	4	...	...	...
?	1	...	...	...	½	1	...	...	2	1	1	...	4	...	2	2½	...	1
Totals ...	20	17½	91	17	20½	63	24	17½	73	24	7	64	36½	10½	60	32	17	59
Classes	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.

Day of month.	July.			August.			September.			October.			November.			December.		
Classes...	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.
1.	...	...	1	...	...	2	...	3	3	1	2	4	1	1	3	...	1	...
2.	...	...	...	...	2	2	...	1	4	...	1½	1	...	...	7	1	1½	7
3.	4	1	1	...	...	8	1	...	2	1	1	4	...	1	4	1	2	3
4.	3½	½	3	2	½	2	3	...	5	...	1½	3	...	1	6	1	...	2
5.	½	1	3	2½	...	5	2	...	5	1	1	3	3	...	2	2	3	4
6.	...	½	...	1	1	6	...	½	5	1	...	2	...	1	8	...	...	1
7.	1	2	...	3	1½	4	2	...	9	1	1	4	1	...	4	1	1	5
8.	2	1	2	1	...	4	...	2	2	1	1	3	...	...	3	2	2	7
9.	½	...	1	...	...	8	2	½	1	...	1	2	...	2	7	1	1	6
10.	...	...	1	1	1	11	2½	...	8	1	...	1	...	...	2	1½	½	3
11.	...	...	3	2	1½	4	...	1	5	1	...	3	...	2	7	1	2	7
12.	1	...	3	1	...	3	...	...	2	1	...	4	1	2	3	1	...	8
13.	½	1	5	...	1	4	2	1	5	4	...	5	1	3	15	4	...	4
14.	2½	...	2	1	...	3	1	...	1	1	...	4	...	...	11	1	2	3
15.	2	...	2	1	½	5	1	1	4	...	...	9	...	2	3	1	1	3
16.	½	...	3	...	...	5	1	...	1	...	...	3	...	...	4	1	...	3
17.	1½	3	6	...	...	3	...	1	...	...	2	5	1	1	5	½	1½	4
18.	...	½	2	...	1½	2	...	...	2	½	...	4	...	1	3	...	...	4
19.	...	...	2	...	...	3	1	1	5	...	1	4	½	1	7	...	...	3
20.	...	3	5	1	1	6	...	1	3	...	...	2	1	4	5	...	...	1
21.	...	1	3	...	...	2	1	...	2	1	...	3	...	2	1	...	2	10
22.	...	...	2	...	...	4	...	...	6	...	1	1	...	½	3	1	...	4
23.	...	...	3	...	½	7	...	½	2	...	1	3	1½	1	2	1	...	1
24.	2	1	3	...	1	1	...	2	3	...	...	4	...	2	...	1	1½	1
25.	...	...	1	2	...	4	...	½	1	1	1	5	1	1	1	2	...	3
26.	2	...	2	...	1	4	...	...	3	2	...	4	...	3	4	...	...	1
27.	...	...	2	...	...	...	...	...	1	...	1	2	2	1	3	3	...	4
28.	1	...	2	...	...	2	...	...	3	...	1	1	1	3	1	...	...	...
29.	½	...	6	...	...	1	...	...	3	1	1	4	1	½	5	...	...	3
30.	1	1	5	1	½	5	...	...	4	1	...	2	3	...	2	...	...	5
31.	1	...	2	...	...	2	...	...	...	1	...	2	...	...	...	...	...	3
?	3	1	2	4	2	2	1	1½	5	...	1	2	3	1½	5	...	1	2
Totals ...	30	17½	78	23½	16½	124	20½	17½	105	21½	20	103	22	37½	136	28	23	115
Classes	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.	A.	B.	C.

III. Meteoric Showers.

1. *The August Meteors in* 1869.—The following Tables of observations in Piedmont are contained in the 'Meteorological Bulletin' of the Moncalieri Observatory, near Turin. The numbers of shooting-stars observed at different stations were, in the hours ending on the nights of—

Number of meteors seen at	August 10th, P.M.						Total numbers.
	10^h.	11^h.	12^h.	13^h.	14^h.	15^h.	
Turin	6	20	16	55	70	43	210
Bra	42	55	17	19	64	(30)	227
Piacenza	49	83	104	110	145	225	716
Padua	43	63	65	74	(20)	......	(265)
Urbino	(3)	16	29	23	20	24	(115)*
	August 11th, P.M.						
Turin	18	19	30	29	31	37	164
Bra	20	34	33	32	...	...	(119)
Piacenza	25	35	41	81	66	...	(248)
Padua	(6)	49	42	(9)	...	...	(106)

It will be seen by an inspection of this Table that the maximum was not yet attained at the time when observations were suspended on the morning of the 11th, and that the horary numbers on the night of the 11th were not so great as on the preceding night. The numbers of shooting-stars observed on the night of the 9th was inconsiderable at all the stations.

2. *Meteor-shower in August* 1869.—Notes on shooting-stars and bolides in Professor Tachini's 'Meteorological Bulletin of the Royal Observatory of Palermo.'—"1869, August 1st, evening. On this night a considerable number of very fine shooting-stars was observed, leaving streaks, some of which remained visible for ten seconds. The radiant-point was between α Scorpii and η Serpentis, at R. A. 252°, S. Decl. 22°."

3. *Meteor-shower in November* 1869.—On the night of November 6th, 1869, Mr. T. W. Backhouse observed twenty-one shooting-stars at West Hendon, Sunderland, twelve of which had a well-defined radiant-point at R. A. $3^h\ 37^m$, N. Decl. 16°. Of ten meteors seen by Mr. Backhouse on the night of the 4th of November, four agreed with this radiant-point. None of the meteors seen at Sunderland on the nights of the 4th and 6th of November, 1869, belonged to the great November shower. (Report of the Observing Astronomical Society on observations in November and December, 1869, 'Astronomical Register' for March 1870).

The position of this radiant-point is scarcely one degree from that assigned by Heis to the radiant-point R_1, appearing, at about the same time of the year, at R. A. 55°, N. Decl. 16°; while it is ten degrees from the position of Greg's radiant-point R G, for the end of October and beginning of November, at R. A. 64°, N. Decl. 18°, not far from α Tauri. Professor Schiaparelli has recently constructed from M. Zezioli's observations, at Bergamo, of about 9000 shooting-stars during the years 1867–69, a table of the positions of radiant-points of forty-four meteoric showers, concluded principally from observations recorded on single nights of the year. Amongst the radiant-points of the Table, M. Zezioli's observations on the 10th of November indicate

* Meteorological Bulletin of the Urbino Observatory for August 1869.

the position of a radiant-point (No. 39 of the following list) at R. A. 70°, N. Decl. 20°, sufficiently near the place of the radiant-point R G to lead Professor Schiaparelli to regard its identity with the latter radiant-point as fully established, while its considerable distance from Heis's radiant-point R_4 appears to separate it from that meteoric shower as a distinct region of radiation.

Table of Radiant-points of Meteor-showers obtained by Professor Schiaparelli from observations of Shooting-stars at Bergamo by G. Zezioli, 1867–69.

Reference number.	Dates of meteoric showers.	Positions of the radiant-point.		Elongation from apex of the earth's way.	Longitude of perihelion.	Longitude of the node.	Inclination (D, direct; R, retrograde).	Perihelion distance.
		R. A.	Decl.					
		°	°	°	°	°	°	
1.	Jan. 11–12 ...	183	+28	38	33	292	56 R	0·595
2.	„ 18.........	232	+36	54	146	298	89 R	0·941
3.	„ 28.........	67	+25	150	147	309	1 D	0·976
4.	„ 28.........	236	+25	44	145	309	74 R	0·981
5.	„ 31.........	134	+40	97	202	312	18 D	0·671
6.	Feb. 6.........	183	+56	81	200	318	49 D	0·735
7.	„ 16.........	74	+48	104	152	328	33 D	0·999
8.	March 20......	144	+48	131	202	0	13 D	0·964
9.	April 2–3......	259	+38	64	223	13	77 D	0·933
10.	„ 10	163	+47	133	219	21	13 D	0·976
10a.	„ 14	168	+47	131	222	25	14 D	0·978
11.	„ 11	193	+20	105	258	22	16 D	0·780
12.	„ 13	231	+27	79	276	24	48 D	0·655
13.	„ 25	142	+53	143	216	35	12 D	1·000
14.	„ 25	260	+24	61	285	35	79 D	0·671
15.	„ 30	237	+35	88	272	40	40 D	0·808
16.	May 22.........	232	+25	103	286	61	25 D	0·854
17.	June 14	280	+35	79	313	83	54 D	0·821
18.	„ 30	240	+19	123	306	99	17 D	0·946
19.	July 18.........	342	+23	39	206	116	53 R	0·500
20.	„ 18.........	324	+69	69	292	116	70 D	0·999
21.	„ 21.........	313	+40	72	355	119	62 D	0·780
22.	„ 28.........	174	+55	104	262	125	27 D	0·866
23.	„ 30–31 ...	275	+37	104	334	127	30 D	0·946
24.	Aug. 4	342	+29	55	48	132	90 D, R.	0·448
25.	„ 10	43	+57	40	343	138	66 R	0·953
26.	„ 10	47	+18	2	318	318	3 D	0·997
27.	„ 11	Pole	North	73	289	139	63 D	0·933
28.	Sept. 5	321	+60	81	15	163	54 D	0·924
29.	„ 6	60	+32	15	309	164	19 R	0·910
30.	„ 18	51	+39	33	273	176	41 R	0·561
31.	„ 28	83	+54	33	337	185	55 R	0·941
32.	Oct. 12.........	53	+27	52	217	199	60 R	0·024
33.	„ 13.........	80	+19	30	280	20	10 R	0·413
34.	„ 21.........	75	+25	42	248	208	7 R	0·117
35.	„ 21.........	130	+48	29	30	208	49 R	1·000
36.	„ 21.........	96	+13	24	313	28	19 R	0·629
37.	„ 21–25 ...	111	+29	13	350	210	9 R	0·883
38.	„ 24.........	77	+45	46	277	211	65 R	0·297
39.	Nov. 10	70	+20	67	192	48	5 D	0·095
40.	„ 10	87	+47	54	286	228	87 R	0·235
41.	„ 23	100	+30	52	259	241	60 R	0·024
42.	„ 26	107	+33	51	273	244	62 R	0·063
43.	„ 30	17	+48	115	103	248	15 D	0·918
44.	Dec. 9	135	+37	44	322	257	57 R	0·289

4. *The November Meteoric Shower in* 1869.—In addition to the observations of the November meteors in 1869, which were received by the Committee, the following are some of the results obtained at the Italian Observatories, where the sky was in general in a more favourable state for observation than the condition of the atmosphere which prevailed in England on the morning of the 14th of November.

The number of meteors seen at the Moncalieri and Perugia Observatories, on the morning of the 14th of November, 1869, were in the half hours (in Perugia in the hours) ending at November 14, 1869, A.M. :—

	h 12	h m 12 30	h 13	h m 13 30	h 14	h m 14 30	h 15	h m 15 30	h 16	h m 16 30	h 17	Total numbers.
Moncalieri......	3	46	57	64	79	70	62	80	80	92	77	710
Perugia	2	...	...	...	39	...	190	...	246	...	71	548

Four maxima of frequency were observed at Moncalieri during the quarters of an hour ending at $1^h\ 45^m$, $3^h\ 15^m$, $4^h\ 15^m$, and $4^h\ 45^m$ A.M. At Perugia the sky was overcast until 1^h A.M., and frequent cumuli crossed the sky during the remainder of the night. The principal maximum frequency of the meteors appeared to occur between 3^h and 4^h A.M.; and the agreement of these observations with the time of maximum at Port Saïd, Alexandria, where the November shower was observed by Captain Tupman, R.M.A., will be gathered from the following Table, which is extracted from the 'Monthly Notices of the Royal Astronomical Society' for December 1869.

1869, November 13th, Alexandria Mean Time.

From	To	Number of meteors seen.	Elevation of radiant-point.
h m	h m		°
10 40	13 15	0	15
14 30	14 40	16	35
14 52	15 2·5	16	40
15 8	19·7	16	43
24	33·6	16	46
38·5	52·5	16	50
59	16 7·4	16	54
16 12	24	16	57
26	38	(6)	60
40	52	(7)	63
16 54	17 14	(4)	67

During the observations included in brackets the sky was cloudy; but in the last two clearer than in the earlier part of the watch. The maximum took place either before or about $14^h\ 30^m$, when the sky was first clear enough to permit a systematic watch, and the number of meteors seen after this began very rapidly to decline until the watch was finally abandoned.

At the Mauritius a letter from the Secretary of the Meteorological Society, Mr. Meldrum, to Mr. Glaisher announced that the November meteors were seen on the morning of the 14th: from midnight until $4^h\ 40^m$ A.M. 439 meteors were counted; and of these, 427 were seen between $3^h\ 20^m$ A.M. and $4^h\ 40^m$ A.M., showing the occurrence of a maximum towards the latter time.

At Pensacola, in Florida, the meteors were very numerous throughout the morning of the 14th, appearing occasionally as frequently as from two or three to twenty in a single minute, but no distinct time of the maximum could be definitely fixed.

At Santa Barbara, California, the number of meteors seen by Mr. George

Davidson and Mrs. E. Davidson in $2^h\ 25^m$, between $1^h\ 15^m$ and $3^h\ 40^m$ A.M., was 556 meteors, the rate of frequency gradually increasing until $2^h\ 20^m$ A.M., when it was five or six meteors in a minute, and again decreasing with frequent minor maxima of abundance until the close of the observations, when the rate of their appearance returned to nearly the same average, of about three per minute, as at the beginning of the observations.

Although the star-shower returned in diminished brilliancy on the morning of the 14th of November, 1869, it is evident, from the examples of these observations, that no well-marked moment of greatest abundance (like those which were observed in 1866 and 1867) was again perceived in the last November star-shower. The meteors seen on the mornings of the 13th and 15th of November were comparatively insignificant in their numbers at all the points of observation.

5. *The August Meteors in* 1870.—The cooperation of observers in England and Scotland having been solicited by the Committee, between the 5th and the 12th of August, 1870, a considerable number of observations were made at the stations, of which the following list furnishes the duration of the watch and the number of the meteors seen by each observer.

A considerable abundance of meteors was observed at Hawkhurst on the night of the 6th, and the second maximum of frequency took place on the night of the 10th of August. On account of full moonlight and occasional clouds on the 10th, with a hazy sky, the hour of maximum was not definitely fixed; but six meteors were mapped in six minutes at Hawkhurst between $12^h\ 12^m$ and $12^h\ 18^m$ A.M. on the night of the 10th–11th. An almost total absence of meteors was observed at Birmingham, the Royal Observatory, Greenwich, East Tisted (Hants), and at Hawkhurst during the half-hour between $11^h\ 15^m$ and $11^h\ 45^m$ P.M. on the night of the 10th; a similar lull in the meteoric shower was observed at Hawkhurst between $11^h\ 10^m$ and $11^h\ 40^m$ P.M. on the following night. The hourly number of meteors seen by two observers at Hawkhurst, between $10^h\ 30^m$ P.M. and $12^h\ 30^m$ A.M., was eleven on the night of the 10th, and nine on the night of the 11th, the sky being equally favourable on both nights.

The following is Mr. Wood's report on the meteoric shower observed at Birmingham:—

"Number of meteors seen per hour by one observer from 11^h till midnight on the nights of August

5th.	6th.	7th.	8th.	9th.	10th.	11th.	12th.	Ratios of brightness of the meteors from August 5th to 12th.
9	11	6	5	2	6	3	2	$>$ 1st mag.*...... 41 per cent. $=$ 1st–3rd mag.* 28 " $<$ 3rd mag.* ... 31 "

"On the night of the 9th, from 10^h to 11^h P.M., one meteor only.

"On the night of the 10th, from $11^h\ 14^m$ to $11^h\ 48^m$ P.M., none.

"Weather favourable for observation throughout, except hazy on the 10th, and full moonlight.

Centres of emanation and rates per cent. from each radiant-point.

	Numbers of meteors per cent.	
η Persei	30	36 per cent. were red or orange-coloured meteors, and the rest were blue, white, or green.
γ Persei	24	
ϵ Cassiopeiæ	12	
$T_{2,3,4}$ and T_1 (in Pegasus) ..	12	
$N_{12,13}$ (near Polaris)	10	
B_4, χ, O_1 (Neumayer)	12	

Place of observation.	Dates of observation and numbers of meteors seen.																Total numbers.	Observers.
	5th.	No.	6th.	No.	7th.	No.	8th.	No.	9th.	No.	10th.	No.	11th.	No.	12th.	No.		
	h m		h m		h m		h m		h m		h m		h m		h m			
Birmingham	11 0 to 12 0	6	11 12 to 12 0	6	11 0 to 12 0	3	11 0 to 12 0	4	11 0 to 12 0	3	11 0 to 12 0	6	11 0 to 12 0	3	11 0 to 12 0	2	33	W. H. Wood.
Broadstairs	over-cast.	...	10 0 to 12 0	2	over-cast.	...	10 0 to 11 0	1	9 30 to 10 30	2	over-cast.	...	do.	...	do.	...	5	Jas. Chapman.
Royal Observatory, Greenwich	......	...	9 0 to 12 15	19	over-cast.	...	10 0 to 11 15	3	9 0 to 13 0	13	9 0 to 13 30	36	9 0 to 12 0	23	9 20 to 11 0	2	96	Mr. Glaisher's six observers: N., J.W., S., M., W.B., & B.
Hawkhurst.........	11 0 to 12 0	3	11 0 to 13 0	30	over-cast.	...	11 0 to 12 0	6	10 0 to 12 0	2	10 30 to 13 0	27	10 30 to 12 30	19	over-cast.	...	87	A. S. Herschel, and J. P. Maclear.
Hay (S. Wales)...	......	...	......	...	......	...	......	...	......	...	10 30 to 13h	5	......	...	......	...	5	T. W. Webb.
London	......	...	......	...	......	...	......	...	......	...	10 0 to 11 30	12	9 30 to 11 30	10	......	...	22	T. Crumplen.
Manchester	10 30 to 12 0	11	10 0 to 12 15	12	over-cast.	...	10 0 to 14 0	11	over-cast.	...	do.	...	do.	...	do.	...	34	R. P. Greg.
E. Tisted (Hants)	10 30 to 12 0	8	......	...	10 0 to 11 0	4	......	...	10 0 to 11 0	2	10 0 to 12 0	10	12 0 to 12 30	1	9 30 to 11 0	5	30	F. Howlett.
Wisbech............	over-cast.	...	do.	...	do.	...	do.	...	do.	...	do.	...	do.	...	do.	...	......	S. H. Miller.
York	......	...	......	...	11 0 to 12 0	7	10 0 to 11 0	1	10 0 to 11 0	7	10 0 to 12 0	13	10 0 to 12 0	9	10 0 to 10 30	1	38	J. E. Clark. (7 meteors on the 7th, between 11 and 12 P.M., observed at Bristol.)
Arrochar (Loch Long).	......	...	......	...	......	...	......	...	10 0 to 11 30	6	10 0 to 11 30	11	10 0 to 11 30	10	10 0 to 10 30	1	28	T. W. Backhouse.
Eyemouth (Berwick).	......	...	......	...	......	...	......	...	10 30 to 11 30	10	10 30 to 11 30	21	14 0 to 14 30	1	......	...	32	Jas. Garden.
Total numbers seen	......	28	......	69	......	14	......	26	......	45	......	141	......	76	......	11	410	

"There was a marked paucity of meteors on and about the 10th; and the August meteoric shower appears to be approaching its minimum, which, as observed in these Reports for 1867 and 1869, might be expected [dating an eight-year period, observed in previous minima, from the minimum of 1862] to take place about the present year. On the present occasion the greatest number occurred on and after midnight of the 6th, preceded by a fireball at $9^h\ 57^m$ P.M. observed at the Isle of Skye, and a more than ordinarily bright meteor at $11^h\ 16^m$ P.M., at Birmingham. There was no change of position of the radiant-points on successive nights, but a continuation of the Perseids, and other centres, with a simple variation in activity."

The radiant-point on the night of the 10th appeared at London (Mr. T. Crumplen) to be near η Persei, at East Tisted (Mr. F. Howlett) near σ Persei, and at Hawkhurst (Mr. A. S. Herschel) near α, γ Persei; on the night of the 11th it appeared to be, at London nearer to χ Persei, and at Hawkhurst between η Persei and ϵ Cassiopeiæ. At Manchester the radiant region on the nights of the 6th–9th of August appeared to Mr. Greg to occupy an elongated space between k Persei and ϵ Cassiopeiæ.

Report on Recent Progress in Elliptic and Hyperelliptic Functions. By W. H. L. Russell, *F.R.S.*

Part III.

Section 1.—In this division I propose to consider modular equations, and some subjects connected with elliptic functions, omitted in the Second Part. The higher portions of the theory of modular equations, which are intimately connected with the theory of numbers, have been already treated by Professor Smith in his valuable report on that branch of mathematics. On the other hand, Professor Sohnke's important paper on modular equations was very slightly noticed by Mr. R. L. Ellis, and therefore, although much earlier in date than the other papers which form the subject of this Report, may well be considered here as an assistance to the reader who is disposed to enter on the researches of Messrs. Kronecker, Hermite, and Joubert, which are closely connected with these investigations of Sohnke.

I shall employ in the following pages μ and ν instead of u and v, as used in the 'Fundamenta Nova,' to prevent (u) occurring in two different senses in the same investigation.

Jacobi has given the following theorem for the transformation of the 5th order:—

$$\frac{dy}{\sqrt{1-y^2}\sqrt{1-\nu^8y^2}}=\frac{\nu-\mu^5}{\nu(1-\mu\nu^3)}\cdot\frac{dx}{\sqrt{1-x^2}\sqrt{1-\mu^8x^2}}$$

if

$$y=\frac{\nu(\nu-\mu^5)x+\mu^3(\mu^2+\nu^2)(\nu-\mu^5)x^5+\mu^{10}(1-\mu\nu^3)x^5}{\nu^2(1-\mu\nu^3)+\mu\nu^2(\mu^2+\nu^2)(\nu-\mu^5)x^2+\mu^6\nu^3(\nu-\mu^5)x^4},$$

where

$$\mu^6-\nu^6+5\mu^2\nu^2(\mu^2-\nu^2)+4\mu\nu(1-\mu^4\nu^4)=0.$$

This last equation is called the modular equation of the 5th order.

Putting $\nu=\sqrt[4]{\lambda}$, $\mu=\sqrt[4]{k}$, the general problem of modular equations, which we have to solve, is the following:—

To determine the relation between λ and k, or μ and ν, so that

$$\frac{dy}{\sqrt{1-y^2}\,\sqrt{1-\lambda^2y^2}}=\frac{dx}{M\sqrt{1-x^2}\,\sqrt{1-k^2x^2}},$$

M being a constant multiplier, and y and x connected by the relation

$$y=\frac{\alpha x+\beta x^3+\gamma x^5+\ldots\ldots+\omega x^{2m+1}}{\alpha'+\beta' x^2+\gamma' x^4+\ldots\ldots+\omega' x^{2m}},$$

We easily derive the following theorem from the 'Fundamenta Nova:'—

$1-k\sin am\, nu=$

$$\frac{1-\lambda\sin am\frac{u}{M}\cdot 1-\lambda\sin am\left(\frac{u}{M}+\frac{4i\Lambda'}{n}\right)\ldots 1-\lambda\sin am\left(\frac{u}{M}+\frac{4(n-1)i\Lambda'}{n}\right)}{\Delta^2 am\frac{4i\Lambda'}{M}\cdot\Delta^2 am\frac{8i\Lambda'}{M}\ldots\Delta^2 am\frac{2(n-1)i\Lambda'}{n}};$$

and substituting in this the values of the factors in the numerator derived from the equation,

$$1-\lambda\sin am\left(\frac{u}{M}+\frac{4m'i\Lambda'}{n}\right)=\frac{\Pi_m{}_{o}^{n-1}\left\{1-k\sin am\left(u+\frac{4mK+4m'iK'}{n}\right)\right\}}{\left\{\Delta\, am\frac{4K}{n}\,\Delta\, am\frac{8K}{n}\ldots\Delta\, am\frac{2(n-1)K}{n}\right\}^2},$$

transforming by the formulæ of page 37 of the 'Fundamenta Nova,' and determining the constant multiplier by putting $n=o$ in both sides of the equation, we have

$1-k\sin am\,(nu)=$

$$(1-k\sin am\,u)\,\Pi_{m'}{}_{-\frac{n-1}{2}}^{\frac{n-1}{2}}\,\Pi_m{}_{o}^{\frac{n-1}{2}}\frac{\left\{1-k\sin am\,u\sin am\,u\frac{4mK+4miK'}{n}\right\}^2}{1-k^2\sin^2 am\,u\sin^2 am\frac{4mK+4m'iK'}{n}},$$

where, however, when $m=0$, $\Pi_{m'}{}_{1}^{\frac{n-1}{2}}$ must be substituted for $\Pi_{m'}{}_{-\frac{n-1}{2}}^{\frac{n-1}{2}}$.

From this Sohnke deduces that symmetrical functions of the quantities $\sin coam\frac{4mK+4m'iK'}{n}$, when m and m' have the values just assigned, are rational and entire functions of k.

Section 2.—We know that

$$\nu=\mu^n\{\sin coam\,4\omega\,\sin coam\,8\omega\ldots\ldots\sin coam\,2(n-1)\omega\};$$

and it appears, from the 'Fundamenta Nova,' that if we put in this equation successively the $(n+1)$ values,

$$\omega=\frac{K}{n},\frac{iK'}{n},\frac{K+iK'}{n}\ldots\ldots\frac{K+(n-1)iK'}{n},$$

we shall have all the possible values of this expression. The values of ν may therefore be represented by the following expression:—

$$\nu=\mu^{\nu}\left\{\sin coam\,\frac{4m\mathrm{K}+4m'i\mathrm{K}'}{n}\cdot\sin coam\,\frac{8m\mathrm{K}+8m'i\mathrm{K}'}{n}\cdot\ldots\ldots\right.$$
$$\left.\sin coam\,\frac{2(n-1)m\mathrm{K}+2(n-1)m'i\mathrm{K}'}{n}\right\},$$

where m' signifies one of the quantities 0, 1, 2, 3 . . . . $(n-1)$, and m is unity, except when $m'=1$, when it is both unity and zero.

We immediately deduce from the 'Fundamenta Nova' the equation

$$\sin coam\,\frac{2\mathrm{K}x}{\pi}=\frac{2}{\mu^2}\sqrt[4]{q}\cos x\Pi\frac{1+2q^{2r}\cos 2x+q^{4r}}{1+2q^{2r-1}\cos 2x+q^{4r-2}}.$$

From this Sohnke proves that the $(n+1)$ values of (ν) may be derived from

$$\mu=\sqrt{2}\sqrt[8]{q}\left\{\frac{(1+q^2)(1+q^4)(1+q^6)\ldots\ldots}{(1+q)(1+q^3)(1+q^5)}\right\}$$

by substituting for q successively in this equation the $(n+1)$ quantities

$$q^n,\ q^{\frac{1}{n}},\ \alpha q^{\frac{1}{n}},\ \alpha^2 q^{\frac{1}{n}}\ \ldots\ldots\ \alpha^{n-1}q^{\frac{1}{n}},$$

α being any of the n roots of unity.

The proof, although long, presents no particular difficulty, and depends on transforming the factors in the continued products by means of the theorem that $2nr\pm4m'p$ (when n is a prime number, m' one of the numbers 1, 2, 3 . . . . . $n-1$, r all numbers from zero to infinity, p all numbers from 0 to $\left.\frac{n-1}{2}\right)$ is an expression representing all even numbers, the sign being neglected.

Section 3.—It appears from this investigation:

A. That the modular equation is of the $(n+1)$th degree.

B. That the coefficients of the equation, when arranged in powers of ν, are rational and entire functions of μ.

C. That the last term of the modular equation is of the form $+\mu^{n+1}$ if (n) is of the form $8r\pm1$, $-\mu^{n+1}$ if n is of the form $8r\pm3$.

This is deduced by Sohnke from the observation that it is a consequence of the multiplication of elliptic functions that all the roots should have the same sign as the quantity

$$\mu^n\left\{\sin coam\,\frac{4\mathrm{K}}{n}\sin coam\,\frac{8\mathrm{K}}{n}\ \ldots\ldots\ \sin coam\,\frac{2(n-1)\mathrm{K}}{n}\right\}.$$

D. The modular equation is unchanged when k and λ are interchanged, therefore the highest power of (μ) cannot exceed $(n+1)$.

E. We have already seen that μ is of the form $\sqrt{2}\sqrt[8]{q}f(q)$. One value of (ν) must therefore be of the form $\sqrt{2}\sqrt[8]{q^n}f(q^n)$. If we substitute this in the modular equation, the irrationality must disappear. Hence in any term of the modular equation $\alpha\mu^m\nu^r$, we must have $\sqrt[8]{q^m}\cdot\sqrt[8]{q^{rn}}=q^s\sqrt[8]{q^t}$, where t is constant for every term. Hence $m+rn=8s+t$, and therefore the modular equation must be made up of terms of the form

$$\nu^r(\alpha\mu^p+\beta\mu^{p+8}+\gamma\mu^{p+16}+\ \ldots\ldots).$$

F. Since μ^{n+1} is of the form $\sqrt[8]{q^{n+1}}\mathrm{R}_1(q)$, and $\mu\nu$ of the form $\sqrt{q^{n+1}}\mathrm{R}_2(q)$, we see the irrationality to be the same in each case. Hence, as the equation necessarily admits of a term $c\mu^{n+1}$, it must also admit of a term of the form $c'\mu\nu$.

G. Since the modular equation remains unaltered when k and l are interchanged, it follows that it must also remain unaltered when μ and $\pm\nu$ are interchanged. The modular equation is of the form

$$\nu^{n+1}+\ .\ .\ .\ +a\mu\nu+\mu^{n+1}=0$$

if n is of the form $8r\pm1$. Here we must manifestly interchange μ and ν, as the equation cannot be reproduced if μ is placed instead of ν, and $-\nu$ instead of μ. On the other hand, the modular equation is of the form

$$\nu^{n+1}+\ .\ .\ .\ +a\mu\nu-\mu^{n+1}=0$$

if (n) is of the form $8r\pm3$. Here we must place μ instead of ν, $-\nu$ instead of μ, as the equation cannot be reproduced if we interchange μ and ν.

H. Hence Sohnke shows that the coefficients of $\mu^m\nu^p$ and $\nu^m\mu^p$ are equal always in magnitude, although differing in sign when $n=8r\pm3$, and p is even. Also that the coefficients of $u^m\nu^p$ and $u^{n+1-m}\nu^{n+1-p}$ are always equal in magnitude, although differing in sign, when $n=8r\pm3$.

J. Lastly, Sohnke proves that when $\mu=1$, the equation necessarily takes the form $(\nu+1)^n(\nu-1)=0$ when n is of the form $8r\pm3$, and $(\nu-1)^{n+1}$ when (n) is of the form $8r\pm1$.

Section 4.—The method of ascertaining the form of the modular equation now becomes manifest.

We determine the indices of μ and ν by E. Then H, J give us relations between the coefficients, which greatly diminish their number considered as independent quantities. Finally, we determine the remaining coefficients by substituting the values of μ and ν expanded in terms of q in the equation, and then equating the coefficients of the powers of q thus obtained to zero.

This method is fully illustrated by Sohnke by an example. He has also added a modification of the process, which will be found useful in practice.

Section 5.—The discriminant of the modular equation is of the form

$$u^{\nu}(1-u^8)^{\nu'}(\mathrm{A}_0+\mathrm{A}_1u^8+\mathrm{A}_2u^{16}+\ .\ .\ .\ .\ .\ +\mathrm{A}_\rho u^{8\rho}).$$

For a proof of this the reader is referred to the concluding section of Professor Betti's Monografia on Elliptic Functions, contained in the third and fourth volumes of the 'Annali di Matematica,' which I am now going to bring under the notice of the reader. Professor Betti has founded his theory on the geometrical basis adopted by Riemann and his followers, and which it is not my object to consider in the present Report. I shall therefore explain at once the connexion between the notation in the Monografia with that we have already employed, and so lead the way to some new aspects of elliptic functions.

Putting $\omega=2\mathrm{K}$, $\omega'=2i\mathrm{K}'$, and therefore $q=\epsilon^{\frac{\pi i\omega'}{\omega}}$, we have, according to Professor Betti's notation,

$$\theta_{1,1}(x)=\frac{\theta_3(o)}{\theta(o)\theta_2(o)}\theta_1\frac{\pi x}{\omega},\ \ \Theta_{1,1}(x)=i\theta_1\left(\frac{\pi x}{\omega}\right)\ \ .\ \ .\ \ .\ \ .\ \ (1)$$

$$\theta_{1,o}(x)=\ \frac{1}{\theta(o)}\ \theta\ \frac{\pi x}{\omega},\ \ \Theta_{1,o}(x)=\theta\left(\frac{\pi x}{\omega}\right)\ \ .\ \ .\ \ .\ \ .\ \ (2)$$

$$\theta_{o,1}(x)=\frac{1}{\theta_2(o)}\cdot\theta_2\frac{\pi x}{\omega},\quad \Theta_{o,1}(x)=\theta_2\left(\frac{\pi x}{\omega}\right) \quad . \quad . \quad . \quad . \quad (3)$$

$$\theta_{o,o}(x)=\frac{1}{\theta_3(o)}\cdot\theta_3\frac{\pi x}{\omega},\quad \Theta_{o,o}(x)=\theta_3\left(\frac{\pi x}{\omega}\right) \quad . \quad . \quad . \quad . \quad (4)$$

This notation allows us to make use of the following definition, which is of fundamental importance throughout Professor Betti's memoir:—

$$\theta_{\mu,\nu}(x)=\epsilon^{(\nu-1)\frac{\pi i x}{\omega}}\frac{\theta_{1,1}\left(x+\frac{\mu-1}{2}\omega+\frac{\nu-1}{2}\omega'\right)}{\theta_{1,1}\left(\frac{\mu-1}{2}\omega+\frac{\nu-1}{2}\omega'\right)}, \quad . \quad . \quad . \quad (5)$$

when

$$\theta_{\mu,\nu}(x+\omega)=\epsilon^{\nu\pi i}\theta_{\mu,\nu}(x),\quad \theta_{\mu,\nu}(x+\omega')=\epsilon^{-\frac{\pi i}{\omega}(2x+\mu\omega+\omega')}\theta_{\mu,\nu}(x)\,; \quad . \quad (6)$$

also

$$\Theta_{\mu,\nu}(z)=\epsilon^{\frac{\pi i}{\omega}\left(\nu z+\frac{\nu^2\omega'}{4}\right)}\Theta_{o,o}\left(z+\frac{\mu\omega}{2}+\frac{\nu\omega}{2}\right). \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

Section 6.—Having thus explained the notation, we come to the following theorem given by Professor Betti (A. D. M. 3. 123):—

$$\begin{aligned}&2\Theta_{\mu,\nu}(z+\omega)\Theta_{\mu',\nu'}(z-w)\Theta_{\mu-\mu',o}(0)\Theta_{o,\nu-\nu'}(0)=\\&\quad P_{o,o}(z)+(-1)^{\mu}P_{o,1}(z)+P_{1,o}(z)+(-1)^{\mu}P_{1,1}(z), \quad . \quad . \quad . \quad . \quad (1)\end{aligned}$$

where

$$P_{\eta,\epsilon}(z)=\Theta_{\mu+\eta,\nu+\epsilon}(z)\Theta_{\mu'+\eta,\nu'+\epsilon}(z)\Theta_{\mu-\mu'+\eta,\epsilon}(w)\Theta_{\eta,\nu-\nu'+\epsilon}(w).$$

The roots of the entire functions $\Theta_{\mu,\nu}(z+w)\ \Theta_{\mu',\nu'}(z-w)$ are respectively of the form

$$-w+(2r+\mu-1)\frac{\omega}{2}+(2s+\nu-1)\frac{\omega'}{2},$$

$$w+(2r+\mu'-1)\frac{\omega}{2}+(2s+\nu-1)\frac{\omega'}{2}:$$

and the theorem is shown to depend on the proposition that these are also roots of the expression

$$F(z)=P_{o,o}(z)+(-1)^{\mu}P_{o,1}(z)+P_{1,1}(z)+(-1)^{\mu}P_{1,1}(z) \quad . \quad . \quad (2)$$

which it appears will be true if

$$\begin{aligned}&\Theta_{\mu-\mu'+1,\nu-\nu'+1}(w)\quad \Theta_{1,1}(w)\quad \Theta_{\mu-\mu',o}\quad (w)\quad \Theta_{o,\nu-\nu'}\quad (w),\\+&\Theta_{\mu-\mu',\nu-\nu'+1}(w)\quad \Theta_{o,1}\,w\quad \Theta_{\mu-\mu'+1,o}(w)\quad \Theta_{1,\nu-\nu'}\quad (w),\\-&\Theta_{\mu-\mu'+1,\nu-\nu'}(w)\quad \Theta_{1,o}\,w\quad \Theta_{\mu-\mu',1}\quad (w)\quad \Theta_{o,\nu-\nu'+1}(w)\\-&\Theta_{\mu-\mu',\nu-\nu'}\quad (w)\quad \Theta_{o,o}(w)\quad \Theta_{\mu-\mu'+1,1}(w)\quad \Theta_{1,\nu-\nu'+1}\,w=0.\end{aligned}$$

The reader will find no difficulty in proving this by means of the formulæ of last section, and the expressions for the periods given by Schellbach, p. 34.

From this theorem Betti deduces the equations:

$$\theta_{1,1}(z+w)\,\theta_{1,1}(z-w)=\theta^2_{1,1}z\,\theta^2_{1,o}(w)-\theta^2_{1,o}(z)\,\theta^2_{1,1}(w),$$

$$\theta_{1,o}(z+w)\,\theta_{1,o}(z-w)=\theta^2_{1,o}z\,\theta^2_{1,o}(w)-k^2\theta^2_{1,1}z\,\theta^2_{1,1}w,$$

$$\theta_{o,1}(z+w)\,\theta_{o,1}(z-w)=\theta^2_{1,o}z\,\theta^2_{o,1}(w)-\theta^2_{1,1}z\,\theta^2_{o,o}w,$$

$$\theta_{o,o}(z+w)\,\theta_{o,o}(z-w)=\theta^2_{1,o}(z)\,\theta^2_{o,o}(w)-k^2\theta^2_{1,1}(z)\,\theta^2_{o,1}(w),$$

and a multitude of other formulæ which it will be unnecessary to consider further here, as they occur in Part II. of this Report in a slightly different form.

Section 7.—Two of these equations are as follows:—

$$\theta_{1,1}(z+w)\,\theta_{1,o}(z-w)=\theta_{1,1}z\,\theta_{1,o}z\,\theta_{o,1}w\,\theta_{o,o}w+\theta_{o,1}z\,\theta_{o,o}z\,\theta_{1,1}w\,\theta_{1,o}w,$$

$$\theta_{1,o}(z+w)\,\theta_{1,1}(z-w)=\theta_{1,1}z\,\theta_{1,o}z\,\theta_{o,1}w\,\theta_{o,o}w-\theta_{o,1}z\,\theta_{o,o}z\,\theta_{1,1}w\,\theta_{1,o}w;$$

putting $z+w$ for z in these equations, adding them together, then dividing by $2w$ and putting $w=o$, we have

$$\theta_{1,o}z\frac{d\theta_{1,1}z}{dz}-\theta_{1,1}z\,\frac{d\,\theta_{1,o}z}{dz}=\theta_{o,o}z\,\theta_{o,1}z.$$

Betti deduces a large number of equations in a similar way, and especially these (A. D. M. 3. 128):—

$$\frac{d^2\log^{\epsilon}\theta_{1,1}(z)}{dz^2}+\frac{\theta^2_{1,o}z}{\theta^2_{1,1}z}=\frac{d^2\log_{\epsilon}\theta_{1,o}z}{dz^2}+k^2\frac{\theta^2_{1,1}z}{\theta^2_{1,o}z}$$

$$=\frac{d^2\log_{\epsilon}\theta_{o,1}z}{dz^2}+\frac{\theta^2_{o,o}z}{\theta^2_{o,1}z}=\frac{d^2\log_{\epsilon}\theta_{o,o}z}{dz^2}+k^2\frac{\theta^2_{o,1}z}{\theta^2_{o,o}z}=\mathrm{C}, \quad . \quad . \quad . \quad (a)$$

where C is an arbitrary constant. To determine its value put

$$\chi_{\mu,\nu}(z)=\epsilon^{-\frac{Cz^2}{2}}\,\theta_{\mu,\nu}(z).$$

The value of C is found without much difficulty to be $=-\dfrac{2\chi'_{1,o}\frac{\omega}{2}}{\omega\chi_{1,o}\frac{\omega}{2}}$, and the preceding equations become:—

$$\frac{d^2\log_{\epsilon}\chi_{1,1}z}{dz^2}=-\frac{\theta^2_{1,o}z}{\theta^2_{1,1}z},\quad \frac{d^2\log_{\epsilon}\chi_{1,o}z}{dz^2}=-k^2\frac{\theta^2_{1,1}z}{\theta^2_{1,o}z},$$

$$\frac{d\log_{\epsilon}\chi_{o,1}z}{dz^2}=-\frac{\theta^2_{o,o}z}{\theta^2_{o,1}z},\quad \frac{d^2\log_{\epsilon}\chi_{o,o}z}{dz^2}=-k^2\frac{\theta^2_{o,1}z}{\theta^2_{o,o}z}.$$

It is then shown (A. D. M. 3. 130) that these equations lead to the following:—

$$\frac{d^2\chi_{1,o}z}{dz^2}+2k^2z\frac{d\chi_{1,o}z}{dz}+2k(1-k^2)\frac{d\chi_{1,o}z}{dk}+k^2z^2\chi_{1,o}(z)=0.$$

$$\frac{d^2\chi_{1,1}z}{dz^2}+2k^2z\frac{d\chi_{1,1}z}{dz}+2k(1-k^2)\frac{d\chi_{1,o}z}{dk}+(1-k^2+k^2z^2)\chi_{1,1}z=0,$$

$$\frac{d^2\chi_{o,1}z}{dz^2}+2k^2z\frac{d\chi_{o,1}z}{dz}+2k(1-k^2)\frac{d\chi_{o,1}z}{dk}+(1+k^2z^2)\chi_{o,}z=0,$$

$$\frac{d^2\chi_{o,o}z}{dz^2}+2k^2z\frac{d\chi_{o,o}z}{dz}+2k(1-k^2)\frac{d\chi_{o,o}z}{dk}+(k^2+k^2z^2)\chi_{o,o}z=0.$$

From these equations we may expand $\chi_{1,o}(z)$ &c. in powers of (z), from which $\theta_{1,o}$ &c. may of course be deduced.

This beautiful process was first given by Dr. Weierstrass, in the fifty-second volume of Crelle's Journal, with a different notation, which I hope to explain to the reader when I treat of the hyperelliptic functions. The process of Betti, however, does not essentially differ from that of Weierstrass. The actual calculation of the coefficients in the expansion of $\chi_{1,o}z$ has been given by Weierstrass at considerable length in the memoir here mentioned.

Section 8.—Let $\eta=\dfrac{2\chi'_{1,o}\frac{\omega}{2}}{\chi'_{1,o}\frac{\omega}{2}}$, then one of the equations (α) of section 7 will give us $\dfrac{d^2\log_\epsilon\theta_{1,o}z}{dz^2}=-\dfrac{\eta}{\omega}-k^2\dfrac{\theta^2{}_{1,1}z}{\theta^2{}_{1,o}z}$; whence, remembering the values of $\theta_{1,1}z$, $\theta_{1,o}(z)$, also that $\dfrac{\theta_3 o^2}{\theta^2{}_2 o}=k^2$ (Schellbach, p. 73), and integrating, we have $k^2\displaystyle\int dz\sin^2\operatorname{am} z=-\frac{\eta z}{\omega}-\frac{d\log_\epsilon\theta_{1,o}z}{dz}+C$ *; and taking the integral from $z=o$ to $z=\dfrac{\omega}{2}$, we have $\eta=-2k^2\displaystyle\int_o^1\frac{y^2dy}{\sqrt{1-y^2}\sqrt{1-k^2y^2}}$.

Again, from equations (α) we may deduce

$$\frac{d^2\log\Theta_{o,o}z}{dz^2}=-\frac{\eta}{\omega}-k\frac{\Theta^2{}_{o,1}z}{\Theta_{o,o}z};$$

we also have

$$\frac{d^2\Theta_{o,o}z}{dz^2}=-4q\frac{\pi^2}{\omega^2}\cdot\frac{d\Theta_{o,o}z}{dq},$$

whence Betti deduces (A. D. M. 3. 136)

$$\frac{d\omega}{dq}=\frac{(\eta+k^2\omega)\omega}{2q\pi^2}.$$

* It will be easily seen that $d\log_\epsilon\theta_{1,o}(z)$ vanishes if $\dfrac{d}{dz}\cdot\theta\left(\dfrac{\pi z}{\omega}\right)$ vanishes, which takes place when $z=o$, or $z=\dfrac{\omega}{z}$.

Section 9.—The roots of $\theta_{\mu,\nu}(nz)$ are all included in the expression

$$\frac{(2r+\mu-1)\omega+(2s+\nu-1)\omega'}{2n} \text{ (A. D. M. 3. 136).}$$

Hence we find

$$\theta_{\mu,\nu}(nz)=\phi(z)\prod_{o}^{n-1}{}_{\alpha}\prod_{o}^{n-1}{}_{\beta}\,\theta_{\mu,\nu}\left(z+\frac{\alpha\omega+\beta\omega'}{n}\right),$$

$\phi(z)$ being an entire function, which has no finite roots.

Putting $z+\omega$, $z+\omega'$ successively for z, we find

$$\phi(z)=C\epsilon^{n(n-1)\frac{\pi i z}{\omega}}.$$

Substituting this expression it is easy to determine the constant, and we obtain

$$\theta_{\mu,\nu}(z)=\epsilon^{n(n-1)\frac{\pi i z}{\omega}}n^{\mu\nu}\frac{\prod\limits_{o}^{n-1}\prod\limits_{o}^{n-1}\theta_{\mu,\nu}\left(z+\frac{\alpha\omega+\beta\omega'}{n}\right)}{\prod\limits_{o}^{n-1}\prod\limits_{o}^{n-1}\theta_{\mu,\nu}\left(\frac{\alpha\omega+\beta\omega'}{n}\right)}.$$

This expression may be transformed, and we obtain the four following expressions:—

$$\theta_{1,1}(nz)=n\theta_{1,o}(z)\Pi_{\alpha}\Pi_{\beta}\left\{\theta^{2}_{1,o}z-\frac{\theta^{2}_{1,o}\left(\frac{\alpha\omega+\beta\omega'}{n}\right)}{\theta^{2}_{1,1}\left(\frac{\alpha\omega+\beta\omega'}{n}\right)}\theta^{2}_{1,1}z\right\}$$

When α extends to all positive values of α less than $\frac{n+1}{2}$, and to all values of β less than n, which are positive, except when $\alpha=o$, and then β is to have all positive values less than $\frac{n+1}{2}$, exclusive of zero. Similarly:—

$$\theta_{1,o}(nz)=\theta_{1,o}z\Pi_{\alpha}\Pi_{\beta}\left\{\theta^{2}_{1,o}z-k^{2}\frac{\theta^{2}_{1,1}\left(\frac{\alpha\omega+\beta\omega'}{n}\right)}{\theta^{2}_{1,o}\left(\frac{\alpha\omega+\beta\omega'}{n}\right)}\theta^{2}_{1,1}z\right\}.$$

$$\theta_{o,1}(nz)=\theta_{o,1}z\Pi_{\alpha}\Pi_{\beta}\left\{\theta^{2}_{1,o}z-\frac{\theta^{2}_{o,o}\left(\frac{\alpha\omega+\beta\omega'}{n}\right)}{\theta^{2}_{o,1}\left(\frac{\alpha\omega+\beta\omega'}{n}\right)}\theta^{2}_{1,1}z\right\}.$$

$$\theta_{o,o}(nz)=\theta_{o,o}z\Pi_{\alpha}\Pi_{\beta}\left\{\theta^{2}_{1,o}z-k^{2}\frac{\theta^{2}_{o,1}\left(\frac{\alpha\omega+\beta\omega'}{n}\right)}{\theta^{2}_{o,o}\left(\frac{\alpha\omega+\beta\omega'}{n}\right)}\theta^{2}_{1,1}z\right\}.$$

This transformation (A. D. M. 3. 138) presents no difficulty if we remember that it is easily deduced from Section 5, 6:—

$$\theta_{\mu,\nu}(z+r\omega+s\omega')=(-1)^{r\nu+\mu s}\epsilon^{-\frac{\pi i s}{\omega}(2z+s\omega')}\theta_{\mu,\nu}(z),$$

whence

$$\theta_{1,1}\left(z+\frac{(n-\alpha)\omega+(n-\beta)\omega'}{n}\right)=\epsilon^{-\frac{\pi i}{\omega}\left(2z-\frac{2\alpha\omega}{n}-\frac{2\beta\omega'}{n}+\omega'\right)}\theta_{\mu,\nu}(z)\theta_{1,1}\left(z-\frac{\alpha\omega}{n}-\frac{\beta\omega'}{n}\right),$$

$$\theta_{1,1}\left(\frac{(n-\alpha)\omega+(n-\beta)\omega'}{n}\right)=-\epsilon^{-\frac{\pi i}{\omega}\left(\frac{2\alpha\omega}{n}+\frac{2\beta\omega'}{n}+\omega'\right)}\theta_{1,1}\left(\frac{\alpha\omega+\beta\omega'}{n}\right).$$

Section 10.—The expression for $\theta_{1,1}(z)$ may be written as follows :—

$$\theta_{1,1}(z)=\frac{\omega}{\pi}\sin\frac{\pi z}{\omega}\prod_{1}^{\infty}\frac{1-2q^{2n}\cos\frac{2\pi z}{\omega}+q^{4n}}{(1-q^{2n})^2},$$

$$\theta_{1,o}(z)=\prod_{o}^{\infty}\frac{1-2q^{2n+1}\cos\frac{2\pi z}{\omega}+q^{4n+2}}{(1-q^{2n+1})^2},$$

$$\theta_{o,1}(z)=\cos\frac{\pi z}{\omega}\prod_{1}^{\infty}\frac{1+2q^{2n}\cos\frac{2\pi z}{\omega}+q^{4n}}{(1+q^{2n})^2},$$

$$\theta_{o,o}(z)=\prod_{o}^{\infty}\frac{1+2q^{2n+1}\cos\frac{2\pi z}{\omega}+q^{4n+2}}{(1+q^{2n+1})^2}.$$

As we are going to enter on investigations in which the values of ω and ω' are transformed, we shall write $\theta_{\mu,\nu}(z,\omega'_1\,\omega)$ instead of $\theta_{\mu,\nu}(z)$.

Then if $\frac{\omega'_1}{\omega_1}=\frac{\omega'}{\omega}$, we shall find :—

$$\left.\begin{aligned}&\theta_{\mu,\nu}(z,\omega'_1\omega_1)=\theta_{\mu,\nu}\left(\frac{z\omega}{\omega_1},\omega',\omega\right),\text{ where }\mu\nu=o\\&\theta_{1,1}(z,\omega'_1\omega_1)=\frac{\omega_1}{\omega}\theta_{1,1}\left(\frac{z\omega}{\omega_1},\omega',\omega\right)\end{aligned}\right\}\text{A.}$$

Professor Betti then shows (A. D. M. 3. 148) that if

$$\omega=\alpha\Omega+\beta\Omega',\ \omega'=\gamma\Omega+\delta\Omega',\ \alpha\delta-\beta\gamma=p,$$

where p is a prime,

$$r\alpha+s\gamma\equiv0,\ r\beta+s\delta\equiv0 \text{ mod. } p,$$

where r and s are less than p, we shall have

$$\theta_{\mu,\nu}(z,\Omega',\Omega)=\phi(z)\prod_{o}^{p-1}{}_t\theta_{\mu',\nu'}\left\{z+t\left(\frac{r\omega+s\omega'}{p}\right)\right\};$$

when

$$\left.\begin{aligned}\mu'&\equiv\delta\mu+\nu\gamma+\gamma\delta\\ \nu'&\equiv\nu\alpha+\mu\beta+\alpha\beta\end{aligned}\right\}\text{ mod. }2^*,$$

when $\phi(z)$ is a function which has no finite roots.

* To understand these congruences, see A. D. M. 3. 140. The congruences $m\delta-n\gamma\equiv t'r$, $n\alpha-m\beta\equiv t's$ (A. D. M. 149) are easily obtained from the preceding by multiplying them by n and m, and subtracting.

By putting $z+\omega$, $z+\omega'$ for (z), and making use of equations (6), section 5, we have

$$\phi(z)=C\epsilon^{-\frac{\pi i}{\omega}\left(\frac{\beta z^2}{\Omega}-(p-1)sz\right)}.$$

C is easily determined from this, and we have

$$\theta_{\mu,\nu}(z,\Omega',\Omega)=\epsilon^{-\frac{\pi i}{\omega}\left(\frac{\beta z^2}{\Omega}-(p-1)sz\right)}\frac{\prod_{o}^{p-1}{}_t\,\theta_{\mu',\nu'}\left\{z+t\left(\frac{r\omega+s\omega'}{p}\right)\right\}}{\prod_{1}^{p-1}{}_t\,\theta_{\mu',\nu'}\left\{t\left(\frac{r\omega+s\omega'}{p}\right)\right\}}.$$

If, then, $\frac{\Omega'}{\Omega}=\frac{\Lambda'}{\Lambda}$, $\frac{\Omega}{\Lambda}=M$, we have from A,

$$M\theta_{1,1}\left(\frac{z}{M},\frac{\Lambda'}{\Lambda}\right)=\epsilon^{-\frac{\pi i}{\omega}\left(\frac{\beta z^2}{M\Lambda}-(p-1)sz\right)}\frac{\prod_{o}^{p-1}{}_t\,\theta_{1,1}\left\{z+t\left(\frac{r\omega+s\omega'}{p}\right)\right\}}{\prod_{1}^{p-1}{}_t\,\theta_{1,1}\left\{t\left(\frac{r\omega+s\omega'}{p}\right)\right\}},$$

$$\theta_{\mu,\nu}\left(\frac{z}{M},\frac{\Lambda'}{\Lambda}\right)=\epsilon^{-\frac{\pi i}{\omega}\left(\frac{\beta z^2}{M\Lambda}-(p-1)sz\right)}\prod_{o}^{p-1}\frac{\theta_{\mu',\nu'}\left\{z+t\left(\frac{r\omega+s\omega'}{p}\right)\right\}}{\theta_{\mu',\nu'}\left\{t\left(\frac{r\omega+s\omega'}{p}\right)\right\}},$$

$\mu\nu\equiv\mu'\nu'\equiv o$, mod. 2.

Betti then shows that $\varpi_\sigma=\frac{\omega'+\sigma\omega}{p}$, with the same $p+1$ values which are used in the 'Fundamenta Nova,' will give us all the generality we require; and consequently if we transform our expressions in a manner similar to that we employed last section, and remember that

$$\frac{\theta_{\mu,\nu}(z+(p-t)t\varpi_\sigma)}{\theta_{\mu,\nu}(p-t)t\varpi_\sigma}=(-1)^{\mu\nu}\frac{\epsilon^{-\frac{2\pi iz}{\omega}}\theta_{\mu,\nu}(z-t\varpi_\sigma)}{\theta_{\mu,\nu}(t\varpi_\sigma)},$$

and multiply the conjugate factors by means of the last four equations of section 6, we shall have the following four equations:—

$$M_\sigma\,\theta_{1,1}\left(\frac{z}{M_\sigma},\frac{\Lambda'_\sigma}{\Lambda_\sigma}\right)=\epsilon^{-\frac{\pi i\beta z^2}{M_\sigma\omega\Lambda_\sigma}}\theta_{1,1}(z)\prod_{1}^{\frac{p-1}{2}}\left(\theta^2_{1,o}z-\frac{\theta^2_{1,o}(t\varpi_\sigma)}{\theta^2_{1,1}(t\varpi_\sigma)}\theta^2_{1,1}z\right),$$

$$\theta_{1,o}\left(\frac{z}{M_\sigma},\frac{\Lambda'_\sigma}{\Lambda}\right)=\epsilon^{-\frac{\pi i\beta z^2}{M_\sigma\omega\Lambda_\sigma}}\theta_{1,o}z\prod_{1}^{p-1}\left(\theta^2_{1,o}z-k^2\frac{\theta^2_{1,1}(t\varpi_\sigma)}{\theta^2_{1,o}(t\varpi_\sigma)}\theta^2_{1,1}z\right),$$

$$\theta_{o,1}\left(\frac{z}{M_\sigma};\frac{\Lambda'_\sigma}{\Lambda_\sigma}\right)=\epsilon^{-\frac{\pi i\beta z^2}{M_\sigma\omega\Lambda_\sigma}}\theta_{o,1}(z)\prod_{1}^{\frac{-1}{2}}{}_t\left(\theta^2_{1,o}z-\frac{\theta^2_{o,o}(t\varpi_\sigma)}{\theta^2_{o,1}(t\varpi_\sigma)}\theta^2_{1,1}z\right),$$

$$\theta_{o,o}\left(\frac{z}{M_\sigma},\frac{\Lambda'_\sigma}{\Lambda_\sigma}\right)=\epsilon^{-\frac{\pi i\beta z^2}{M_\sigma\omega\Lambda_\sigma}}\theta_{o,o}(z)\prod_{1}^{\frac{p-1}{2}}{}_t\left(\theta^2_{1,}\quad-k^2\frac{\theta^2_{o,1}(t\varpi_\sigma)}{\theta^2_{o,o}(t\varpi_\sigma)}\theta^2_{1,1}z\right).$$

From these expressions it is easily seen that the ordinary formulæ relative to the transformation of elliptic functions may be deduced. This has been done by Betti (A. D. M. 4. 26 & 57). Many of the results are, of course, as must be the case in a systematic treatise, among those exceedingly well known.

Section 11.—We have already given in section 11, Part II. of the present report, the expressions deduced by Meyer for $\frac{dk}{dq}$ and $\frac{dk'}{dq}$, also in section 8 of our present division, $\frac{d\omega}{dq}$. To these may be added the following (A. D. M. 4. p. 64), in which Y_σ is what η becomes when k is transformed into λ_σ:—

$$\frac{d\log_\epsilon\sqrt{\frac{\pi}{\lambda'_\sigma\Lambda_\sigma}}}{dq}=-\frac{Y_\sigma\Lambda_\sigma}{4pq\pi^2},$$

$$\frac{d\log_\epsilon\sqrt{\frac{\pi}{\lambda_\sigma\Lambda_\sigma}}}{dq}=-\frac{(Y_\sigma+\Lambda_\sigma)\Lambda_\sigma}{4pq\pi^2},$$

$$\frac{d\log_\epsilon\sqrt{\frac{\pi}{\Lambda_\sigma}}}{dq}=-\frac{(Y_\sigma+\lambda^2_\sigma\Lambda_\sigma)\Lambda_\sigma}{4pq\pi^2}.$$

Section 12.—In the papers contributed by Jacobi to the earlier numbers of Crelle's Journal, several propositions may be found which are not contained in the 'Fundamenta Nova.' One of the most celebrated of these has been the subject of a special memoir by Professor Cayley*. It is this. If $u=\sqrt{k}\sin\operatorname{am} z$, and

$$\sqrt{k}\sin\operatorname{am} uz=(-1)^{\frac{n-1}{2}}u\,.\,\frac{u^{n^2-1}+A_1u^{n^2-3}+Au^{n^2-5}+\ldots(-1)^{\frac{n^2-1}{2}}u}{1+A_1u+A_2u^4+\ldots(-1)^{\frac{n^2-1}{2}}nu^{\frac{n^2-1}{2}}},$$

also $\alpha=k+\frac{1}{k}$, then the denominator of this expression will satisfy the differential equation:

$$(1-\alpha u^2+u^4)\frac{d^2U}{du^2}+(n^2-1)(\alpha u-2u^3)\frac{dU}{du}+n^2(n^2-1)u^2U=2n^2(\alpha^2-4)\frac{dU}{d\alpha}.$$

A demonstration of this proposition has also been given by Betti (A. D. M. 4. 32), and another proposition given by Jacobi will be found at p. 13 of the same volume.

Section 13.—Since the publication of the 'Fundamenta Nova' the third elliptic integral has been discussed by Jacobi in his memoir "Sur la Rotation d'un Corps," in the 39th volume of Crelle's Journal, by Betti, 'Annali di Matematica,' iii. 309, and by Schellbach, 'Lehre von den Elliptischen Integralen,' p. 217.

* See also another paper by Professor Cayley, in which this subject is introduced, "Sur la multiplication des fonctions elliptiques," Crelle, xxxix. p. 16.

The following formulæ may be regarded as fundamental; they may be seen proved in Schellbach, Section 130:—

$$faf'a\int_0^x \frac{fx^2dx}{1-fa^2fx^2}=xl'\theta(a)+\tfrac{1}{2}l.\frac{\theta(a-x)}{\theta(a+x)},$$

$$faf'a\int_0^x \frac{dx}{fx^2-fa^2}=xl'\theta(a)+\tfrac{1}{2}l.\frac{\theta_1(a-x)}{\theta_1(a+x)},$$

$$-hah'a\int_0^x \frac{hx^2dx}{ha^2hx^2-1}=xl'\theta(a)+\tfrac{1}{2}l.\frac{\theta_2(a-x)}{\theta_2(a+x)},$$

$$-gag'a\int_0^x \frac{gxdx}{ga^2gx^2+1}=xl'\theta(a)+\tfrac{1}{2}l.\frac{\theta_3(a-x)}{\theta_3(a+x)}.$$

There is also a paper on the third elliptic integral by Professor Somoff in the 47th volume of Crelle's Journal, written to facilitate the numerical calculation of its value. There are a few papers on elliptic functions, connected with Abel's theorem, and the multiplication of functions Θ, which I hope to consider hereafter, when treating on hyperelliptic functions, with which they are closely related.

Section 14.—I have long wished to see a treatise on elliptic functions written on the following plan. First, I have wished the subject to be considered as if consisting of three parts—evolution, division, and transformation. This, indeed, has been in great part effected in Abel's great memoir on the subject; but this memoir, it will be observed, contains no indication of the existence of the functions θ*. The evolution of elliptic functions should be effected in the following way:—They should be expressed by doubly infinite products, and this should be done by a method closely resembling that employed by Abel. These doubly infinite products should then be transformed into the singly infinite products used by Jacobi; and lastly, these singly infinite products should be multiplied together, so as to form the functions θ. The division and transformation should be effected separately, and the evolution deduced as effected by Abel, and not in an elementary treatise, derived from transformation, as we see in the 'Fundamenta Nova.'

An excellent treatise on elliptic functions, which forms a part of Bertrand's 'Traité de Calcul Differentiel et de Calcul Integral,' now publishing in France, keeps these objects steadily in view, and I have great pleasure in recommending it to the reader. If I do not dwell longer on this work, it is not assuredly because I am insensible to its merit, but because it is not only written in the highest style of mathematical elegance, but is also so perspicuous that any commentary from me would be superfluous.

PART IV.

Section 1.—It will be well to commence this part of our work with showing how elliptic functions may be applied to finding the area of the surface of an ellipsoid.

Let $ax^2+by^2+cz^2=1$ be the equation to the surface of an ellipsoid, γ the angle which the normal makes with the axis of (z), ϕ the angle which the

* He alludes, however, to these functions in his subsequent writings, after the discoveries of Jacobi.

line joining the projection of any point on the plane xy to the intersection of the normal with the same plane makes with the axis of (x), then Schellbach shows (p. 300) that if S be the surface of the ellipsoid,

$$S=8abc\int_o^{\frac{\pi}{2}}\int_o^{\frac{\pi}{2}}\frac{\sin\gamma\, d\gamma\, d\phi}{(bc\cos^2\phi\sin^2\gamma+ca\sin^2\phi\sin^2\gamma+ab\cos^2\gamma)^2}.$$

If we put $\sqrt{\frac{a}{c}}=\cos\tau$, $\sqrt{\frac{b}{c}}=\cos\rho$, the expression for the surface becomes

$$\frac{2\pi}{c}\sqrt{\frac{b}{a}}\int_o^{\frac{\pi}{2}}\frac{\sin\gamma d\gamma}{(1-\sin^2\tau\cos^2\gamma)^{\frac{1}{2}}(1-\sin^2\rho\cos^2\gamma)^{\frac{3}{2}}}$$

$$+\frac{2\pi}{c}\sqrt{\frac{a}{b}}\int_o^{\frac{\pi}{2}}\frac{\sin\gamma d\gamma}{(1-\sin^2\tau\cos^2\gamma)^{\frac{3}{2}}(1-\sin^2\rho\cos^2\gamma)^{\frac{1}{2}}}.$$

If we put $\sin\tau\cos\gamma=\frac{f(x)}{\sqrt{k}}$, $\sin\rho\cos\gamma=\sqrt{k}f(x)$, $k=\frac{c-b}{\sqrt{c-a}}$, and therefore $k'=\frac{\sqrt{b-a}}{\sqrt{c-a}}$, the expression for the surface may be written thus:—

$$S=2\pi\frac{\sqrt{c-a}}{\sqrt{abc}}\left\{\frac{l'\theta_3(x)}{\theta_3{}^2o}+\frac{\sqrt{ac}}{\sqrt{b(c-a)}}+x\left(\frac{c\theta_3{}^2o}{c-a}-\frac{\theta''o}{\theta o\theta_3{}^2o}\right)\right\}.$$

Section 2.—A most interesting application of the theory of elliptic functions to mechanics will be found in the 39th volume of Crelle's Journal. In that volume is published Jacobi's memoir on the motion of a rigid body, which has been already mentioned in Part II. of this Report in relation to the many important discoveries it contains in pure mathematical science. I now enter upon the consideration of this paper regarded as a physical memoir. Jacobi makes use of the following notation. Instead of

$$\Theta\frac{2Kx}{\pi},\ H\frac{2Kx}{\pi},\ \Theta\frac{2K}{\pi}\left(x+\frac{\pi}{z}\right),\ H\frac{2K}{\pi}\left(x+\frac{\pi}{z}\right),$$

he writes

$$\Theta\frac{2Kx}{\pi},\ H\frac{2Kx}{\pi},\ \Theta_1\frac{2Kx}{\pi},\ H_1\frac{2Kx}{\pi}.$$

The object of the paper is to calculate the motion of a rigid body, acted on by no forces, round a fixed point.

Let x, y, z be the fixed axes passing through the fixed point to which the motion of the body is referred, the plane of $x\ y$ being the invariable plane.

x_1, y_1, z_1 the principal axes, p, q, r the velocities of rotation round the axes of x_1, y_1, z_1.

θ the inclination of the plane x_1, y_1 to the plane of $x\ y$.

ψ the angular distance of the line of intersection of these planes from the axis of (x).

ϕ the angular distance of the axis of x_1 from the same line of intersection.

$$x=\alpha\ x_1+\beta\ y_1+\gamma\ z_1.$$

$$y=\alpha'\ x_1+\beta'\ y_1+\gamma'\ z_1.$$

$$z=\alpha''x_1+\beta''y_1+\gamma''z_1.$$

To calculate these nine direction cosines in terms of function θ may be regarded as the leading physical object of this memoir. They are connected with the angles θ, ϕ, ψ by the well-known equations:

$$\begin{aligned}
\alpha\ &= \cos\theta\sin\phi\sin\psi + \cos\phi\cos\psi, \\
\alpha' &= \cos\theta\sin\phi\cos\psi - \cos\phi\sin\psi, \\
\alpha'' &= -\sin\theta\sin\phi, \\
\beta\ &= \cos\theta\cos\phi\sin\psi - \sin\phi\cos\psi, \\
\beta' &= \cos\theta\cos\phi\cos\psi + \sin\phi\sin\psi, \\
\beta'' &= -\sin\theta\cos\phi, \\
\gamma\ &= \sin\theta\sin\psi, \\
\gamma' &= \sin\theta\cos\psi, \\
\gamma'' &= \cos\theta.
\end{aligned}$$

Then if A, B, C be the moments of inertia round the principal axes, we have

$$\left.\begin{aligned} \mathrm{A}\,p^2+\mathrm{B}\,q^2+\mathrm{C}\,r^2&=h \\ \mathrm{A}^2p^2+\mathrm{B}^2q^2+\mathrm{C}^2r^2&=l^2, \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (1)$$

$$\frac{d\psi}{dt} = -\frac{\mathrm{A}\,p^2+\mathrm{B}\,q^2}{\mathrm{A}^2p^2+\mathrm{B}^2q^2}l \quad \ldots\ldots\ldots \quad (2)$$

$$\frac{\mathrm{A}p}{l} = -\sin\theta\sin\phi,\ \frac{\mathrm{B}q}{l} = -\sin\theta\cos\phi,\ \frac{\mathrm{C}r}{l} = \cos\theta \quad \ldots \quad (3)$$

It follows from this that we are able to write:

$$p = -\sqrt{\frac{l^2-\mathrm{C}h}{\mathrm{A}(\mathrm{A}-\mathrm{C})}}\cos\xi,$$

$$q = \sqrt{\frac{l^2-\mathrm{C}h}{\mathrm{B}(\mathrm{B}-\mathrm{C})}}\sin\xi,$$

$$r = \sqrt{\frac{\mathrm{A}h-l^2}{\mathrm{C}(\mathrm{A}-\mathrm{C})}}\Delta\xi = \frac{\sqrt{\mathrm{A}h-l^2}}{\sqrt{\mathrm{C}(\mathrm{A}-\mathrm{C})}}\sqrt{1-k^2\sin^2\xi},$$

where ξ is a subsidiary angle, and $k = \dfrac{\sqrt{(\mathrm{A}-\mathrm{B})(\mathrm{B}h-l^2)}}{\sqrt{(\mathrm{B}-\mathrm{C})(\mathrm{A}h-l^2)}}$.

Substituting these values of p, q, r in $\mathrm{B}\dfrac{dq}{dt} + (\mathrm{A}-\mathrm{C})\,rp = o$, and putting $u = nt$, where $n = \dfrac{\sqrt{(\mathrm{B}-\mathrm{C})(\mathrm{A}h-l^2)}}{\sqrt{\mathrm{ABC}}}$, we have

$$du = \frac{d\xi}{\sqrt{1-k^2\sin^2\xi}}, \text{ where } k = \frac{\sqrt{(\mathrm{A}-\mathrm{B})(\mathrm{B}h-l^2)}}{\sqrt{(\mathrm{B}-\mathrm{C})(\mathrm{A}h-l^2)}}; \text{ so that}$$

$$p = -\frac{\sqrt{l^2-\mathrm{C}h}}{\sqrt{\mathrm{A}(\mathrm{A}-\mathrm{C})}}\cos\operatorname{am} u,$$

$$q = \frac{\sqrt{l^2-Ch}}{\sqrt{B(B-C)}} \sin \text{am}\, u,$$

$$r = \frac{\sqrt{Ah-l^2}}{\sqrt{C(A-C)}} \Delta\, \text{am}\, u,$$

which express the velocities about the principal axes in elliptic functions.

Now, substituting these values of p and q in equation (2) and integrating, we have

$$\psi = -l\frac{\sqrt{BC}}{\sqrt{A(B-C)(Ah-l^2)}}\left\{u + \frac{(A-B)(A-C)}{A(B-C)}\int\frac{\sin^2 \text{am}\, u\, du}{1-k^2\sin^2 \text{am}\, ia \sin^2 \text{am}\, u}\right\},$$

where

$$-k^2 \sin^2 \text{am}\, ia^* = \frac{C(A-B)}{A(B-C)},$$

which gives

$$\psi = -nn't + \frac{1}{2i}\log_e \frac{\Theta(u+ia)}{\Theta(u-2a)},$$

where

$$n' = l\frac{\sqrt{BC}}{\sqrt{A(B-C)(Ah-l^2)}} - \frac{d \log_e \Theta ia}{da}.$$

Now let $\psi' = \psi + nn't$, then $\psi' = \frac{1}{2i}\log_e \frac{\Theta(u+ia)}{\Theta(u-ia)}$.

Hence if we cause the axis of (x), instead of remaining fixed, to revolve with a velocity nn' round the axis of (z), we may substitute for α, α', α'' the following values in place of those before obtained:—

$$\begin{aligned}
\alpha &= \cos\theta \sin\phi \sin\psi' + \cos\phi \cos\psi', \\
\alpha' &= \cos\theta \sin\phi \cos\psi' - \cos\phi \sin\psi', \\
\alpha'' &= -\sin\theta \sin\phi, \\
\beta &= \cos\theta \cos\phi \sin\psi' - \sin\phi \cos\psi', \\
\beta' &= \cos\theta \cos\phi \cos\psi' + \sin\phi \sin\psi', \\
\beta'' &= -\sin\theta \cos\phi, \\
\gamma &= \sin\theta \sin\psi', \\
\gamma' &= \sin\theta \cos\psi', \\
\gamma'' &= \cos\theta,
\end{aligned}$$

where

$$2\cos\psi' = \frac{\Theta(u+ia)+\Theta(u-ia)}{\{\Theta(u+ia)\,\Theta(u-ia)\}^{\frac{1}{2}}},$$

$$2i\sin\psi' = \frac{\Theta(u+ia)-\Theta(u-ia)}{\{\Theta(u+ia)\,\Theta(u-ia)\}^{\frac{1}{2}}},$$

* It must be remembered that since A, B, C are in order of magnitude, $-k^2\sin^2 \text{am}\, ia$ must be positive.

$$\cos\theta^{*} = \frac{\mathrm{H}(ia)\,\Theta_1 u}{i\mathrm{H}_1 ia\,\mathrm{H}u},$$

$$\cos\phi = -\frac{\Theta_1 ia\,\mathrm{H}u}{\mathrm{H}_1(0)\Theta^{\frac{1}{2}}(u+ia)\,\Theta^{\frac{1}{2}}(u-ia)}$$

and so substituting and reducing, we obtain the following expressions for the nine cosines:—

$$\alpha = -\frac{\Theta_1(0)\{\mathrm{H}(u+ia)+\mathrm{H}(u-ia)\}}{2\mathrm{H}_1(ia)\,\Theta(u)},$$

$$\alpha' = \frac{\Theta_1(0)\{\mathrm{H}(u+ia)-\mathrm{H}(u-ia)\}}{2i\,\mathrm{H}_1(ia)\,\Theta(u)},$$

$$\alpha'' = -\frac{\Theta(ia)\,\mathrm{H}_1 u}{\mathrm{H}_1(ia)\,\Theta(u)},$$

$$\beta = -\frac{\Theta(0)\{\mathrm{H}_1(u+ia)+\mathrm{H}_1(u-ia)\}}{2\mathrm{H}_1(ia)\,\Theta u},$$

$$\beta' = \frac{\Theta(0)\{\mathrm{H}_1(u+ia)-\mathrm{H}_1(u-ia)\}}{2i\mathrm{H}_1(ia)\,\Theta u},$$

$$\beta'' = \frac{\Theta_1(ia)\,\mathrm{H}u}{\mathrm{H}_1(ia)\,\Theta u},$$

$$\gamma = \frac{\mathrm{H}_1(0)\{\Theta(u+ia)-\Theta(u-ia)\}}{2i\mathrm{H}_1 ia\,\Theta u},$$

$$\gamma' = \frac{\mathrm{H}_1(0)\{\Theta(u+ia)+\Theta(u-ia)\}}{2\mathrm{H}_1(ia)\,\Theta u},$$

$$\gamma'' = \frac{\mathrm{H}(ia)\,\Theta_1 u}{i\mathrm{H}_1 ia\,\Theta u}.$$

These functions can, of course, be expanded in series by the formulæ given in section 10, Part II. of this Report. Jacobi in his memoir enters into a discussion of the ambiguities occasioned by the use of the symbol $i=\sqrt{-1}$, which I omit here, my object being to give a clear insight into the principle of the method by which the problem of the motion of a rigid body round a fixed point is solved.

Section 3.—In the 50th volume of Crelle's Journal there is a memoir by Lottner on the motion of a rigid solid of revolution round a fixed point which is not its centre of gravity, but which is situated in the axis of revolution. This memoir is very similar in its character to Jacobi's. I shall content myself therefore with giving results.

The equations of motion are given by Poisson in the following form:—

$$\mathrm{C}n\cos\theta - \mathrm{A}\sin^2\theta\frac{d\psi}{dt} = l,$$

$$\mathrm{A}\left(\sin^2\theta\frac{d\psi^2}{dt^2}+\frac{d\theta^2}{dt^2}\right) = 2\mathrm{P}\gamma\cos\theta + h,$$

$$\frac{d\phi}{dt} = n + \cos\theta\frac{d\psi}{dt},$$

* These values of $\cos\theta$ and $\cos\phi$ are of course derived from equations (3).

where A and C are the moments round the x_1 and z_1 axes, z_1 being the axis of revolution,
γ the distance of the centre of gravity from the plane of $x_1\, y_1$,
(n) the constant angular velocity round the axis of revolution,
(l) the moment of the quantity of motion of all the points of the body relative to the vertical axis of z,
(h) a quantity introduced by the integration.

Then if α_1, α_2, α_3 are the three roots of the cubic equation,

$$(2\mathrm{AP}\gamma\xi+\mathrm{A}h)(1-\xi^2)-(\mathrm{C}n\xi-l)^2=0\,;$$

when $-\alpha_3$ is greater than unity, and α_1, α_2 lie between -1 and $+1$, k the modulus of the elliptic functions employed in the solution $=\dfrac{\sqrt{\alpha_1-\alpha_2}}{\sqrt{\alpha_1-\alpha_2}}$, so that

$$k'=\frac{\sqrt{\alpha_2-\alpha_3}}{\sqrt{\alpha_1-\alpha_3}},\ \sin^2 am\, ia_1=-\frac{\alpha_1-\alpha_3}{\alpha_1-\alpha_1},\ \sin^2 am\,(ia_2+\mathrm{K})=\sin^2 coam\, ia_2=\frac{\alpha_1-\alpha_3}{1+\alpha_1},$$

where

$$i=\sqrt{-1},\ \mathrm{K}=\int_o^{\frac{\pi}{2}}\frac{d\phi}{\sqrt{1-k^2\sin^2\phi}},$$

$$a_2=\int_o^{\frac{\sqrt{-(1+\alpha_3)}}{\sqrt{\alpha_2-\alpha_3}}}\frac{dx}{\sqrt{1-x^2}\sqrt{1-k^2x^2}},$$

$$a_1=\int_o^{\frac{\sqrt{\alpha_1-\alpha_3}}{\sqrt{1-\alpha_3}}}\frac{dx}{\sqrt{1-x^2}\sqrt{1-k^2x^2}},$$

$$m=\sqrt{\frac{\mathrm{P}\gamma}{2\mathrm{A}}(\alpha_1-\alpha_3)},\ m(t-t_o)=u,$$

$$\mathrm{H}(i(a_1+a_2)+\mathrm{K})\ \mathrm{H}(i(a_1-a_2)-\mathrm{K})=\mathrm{D},$$

$$\Theta(u-ia_1)=\mathrm{A}_1,\ \Theta(u+ia_1)=\mathrm{B}',$$

$$\Theta(u-ia_2-\mathrm{K})=\mathrm{A}'',\ \Theta(u+ia_2+\mathrm{K})=\mathrm{B}''.$$

Then α, α', α'', β, &c. being the same nine direction cosines as before,

$$\alpha=\frac{1}{2\mathrm{D}}\cdot\frac{\mathrm{H}^2ia_1(\mathrm{B}''^2+\mathrm{A}''^2)-\mathrm{H}^2(ia_2+\mathrm{K})(\mathrm{B}'^2+\mathrm{A}'^2)}{\Theta^2u},$$

$$\alpha'=\frac{1}{2i\mathrm{D}}\cdot\frac{\mathrm{H}^2ia_1(\mathrm{B}''^2-\mathrm{A}''^2)-\mathrm{H}^2(ia_2+\mathrm{K})(\mathrm{B}'^2-\mathrm{A}'^2)}{\Theta^2u},$$

$$\alpha''=\frac{\mathrm{H}ia_1\mathrm{H}(ia_2+\mathrm{K})}{\mathrm{D}}\cdot\frac{\mathrm{B}'\mathrm{A}''-\mathrm{A}'\mathrm{B}''}{\Theta^2u},$$

$$\beta=-\frac{1}{2i\mathrm{D}}\cdot\frac{\mathrm{H}^2ia_1(\mathrm{B}''^2-\mathrm{A}''^2)+\mathrm{H}^2(ia_2+\mathrm{K})(\mathrm{B}'^2-\mathrm{A}'^2)}{\Theta^2u},$$

$$\beta'=\frac{1}{2\mathrm{D}}\cdot\frac{\mathrm{H}^2ia_1(\mathrm{B}''^2-\mathrm{A}''^2)+\mathrm{H}^2(ia_2+\mathrm{K})(\mathrm{B}'^2+\mathrm{A}'^2)}{\Theta^2u},$$

$$\beta''=\frac{\mathrm{H}ia_1\mathrm{H}(ia_2+\mathrm{K})}{i\mathrm{D}}\cdot\frac{\mathrm{B'A''+A'B''}}{\Theta^2u},$$

$$\gamma=-\frac{\mathrm{H}ia_1\mathrm{H}(ia_2+\mathrm{K})}{\mathrm{D}}\cdot\frac{\mathrm{B'B''-A'A''}}{\Theta^2u},$$

$$\gamma'=-\frac{\mathrm{H}ia_1\mathrm{H}(ia_2+\mathrm{K})}{i\mathrm{D}}\cdot\frac{\mathrm{B'B''+A'A''}}{\Theta^2u},$$

$$\gamma''=\frac{1}{\mathrm{D}}\cdot\frac{\mathrm{H}^2ia_1\mathrm{B''A''}+\mathrm{H}^2(ia_2+\mathrm{K})\mathrm{B'A'}}{\Theta^2u},$$

where the axis of (x) revolves about the azis of z with an angular velocity

$$=m\left\{\frac{d\log_\epsilon \mathrm{H}ia_1}{da_1}+\frac{d\log_\epsilon \mathrm{H}(ia_2+\mathrm{K})}{da_2}\right\},$$

and the axis of x_1 round the axis of z_1 with an angular velocity

$$=\frac{n(\mathrm{A}-\mathrm{C})}{\mathrm{A}}-m\left\{\frac{d\log_\epsilon \mathrm{H}ia_1}{da_1}-\frac{d\log_\epsilon \mathrm{H}(ia_2+\mathrm{K})}{da_2}\right\}.$$

There is also, in the 50th volume of Crelle's Journal, an elaborate memoir on the application of the functions θ to the solution of the problem of ascertaining the motion of the spherical pendulum, by Dumas.

Section 4.—It will be interesting, in writing on elliptic functions in a country so dependent for its greatness, under Providence, upon its manufacturing skill as this, to show that these integrals are capable of a direct application to machinery. A remarkable example of this is given by Canon Moseley in his 'Mechanics.'

The quantity of work done by a pressure P acting through a space S, where P and S are constant, is taken to be equal to PS. Hence if P is variable, the work done is equal to $\int \mathrm{P}d\mathrm{S}$, or half the *vis viva* accumulated while the work is being done. Canon Moseley then shows that in any machine, if U_1 is the work done at its moving point through the space S, U_2 the work yielded at the working points, U_1 and U_2 are connected together by an equation of the form $\mathrm{U}_1=\mathrm{AU}_2+\mathrm{BS}$, where A and B are constants dependent for their value upon the construction of the machine,—that is to say, upon the dimensions and combination of its parts, their weights, and the coefficients of friction at the various rubbing-surfaces. Upon this principle Canon Moseley works out his theory, and the above equation is applied to the wheel and axle, to pulleys combined in different ways, to toothed wheels, and to all the component parts of machinery, affording in many cases, and especially with regard to toothed wheels, results of great interest and beauty.

In the case of the capstan, the above equation leads to an elliptic function.

Let a_1 be the length of the lever turning the capstan measured from the axis;

a_2 the length of the perpendicular upon the rope supposed to act in a constant direction;

T the tension of the rope;

U_1 the work done by the pressure applied to the extremity of the lever always perpendicular to its direction;

U_2 the work actually performed by the capstan;

ρ the radius of the axle, and ϕ the limiting angle of resistance. For a full explanation of this latter quantity I must refer the reader to the original treatise.

Then if T be supposed constant,

$$U_1=U_2+\frac{T\rho\sin\phi}{a_1}\int d\theta\sqrt{a_1^2+2a_1a_2\cos\theta+a_2^2}.$$

This integral is, of course, the elliptic function E; and the result is strongly suggestive of the importance of the higher integrals in a calculation of work done in machines, when the point of application of the motive power is variable. It is hardly necessary to observe that the radical in the above integral gives the distance between the points of application of the forces.

Committee for the purpose of promoting the extension, improvement, and harmonic analysis of Tidal Observations. Consisting of Sir William Thomson, *LL.D., F.R.S.*, Prof. J. C. Adams, *F.R.S.*, The Astronomer Royal, *F.R.S.*, J. F. Bateman, *F.R.S.*, Admiral Sir Edward Belcher, *K.C.B.*, T. G. Bunt, Staff-Commander Burdwood, *R.N.*, Warren De La Rue, *F.R.S.*, Prof. Fischer, *F.R.S.*, J. P. Gassiot, *F.R.S.*, Prof. Haughton, *F.R.S.*, J. R. Hind, *F.R.S.*, Prof. Kelland, *F.R.S.*, Staff-Captain Moriarty, *C.B.*, J. Oldham, *C.E.*, W. Parkes, *M. Inst. C.E.*, Prof. B. Price, *F.R.S.*, Rev. C. Pritchard, *LL.D., F.R.S.*, Prof. Rankine, *LL.D., F.R.S.*, Captain Richards, *R.N., F.R.S.*, Dr. Robinson, *F.R.S.*, General Sabine, *President of the Royal Society*, W. Sissons, Prof. Stokes, *D.C.L., F.R.S.*, T. Webster, *M.A., F.R.S.*, and Prof. Fuller, *M.A., and* J. F. Iselin, *M.A., Secretaries.*

41. The Committee have to report that the superintendence of the work for the past year has been wholly undertaken by Sir William Thomson. That work has consisted in the reduction of observations and determination of constants by Mr. Roberts and assistants, according to the method which has been fully described in the Report of 1868. For the details of the results obtained, the Committee beg leave to refer to the statements by Sir William Thomson which are appended hereto.

W. Parkes.
George Henry Richards.
W. J. Macquorn Rankine.
J. C. Adams.

Exeter, August 1869.

Report for 1869 *by* Sir W. Thomson.

42. From the Meeting of the British Association at Norwich (Aug. 1868) up to the present time the harmonic reduction of observations recorded by self-registering tide-gauges in several different localities, namely Ramsgate, Bombay, Liverpool, and Fort Point, California, has been continued. The

work has been performed by Mr. E. Roberts and assistant calculators in the Nautical Almanac Office, working under his immediate direction, according to the plans described in the Report presented by the Committee of 1867–68 to the Association at Norwich a year ago, with modifications suggested by experience, and extensions to include parts of the investigation not reached in the first year's work. The results obtained up to January 1869 are described in a supplement to that report, which has been printed, and is published in the yearly volume of the Association.

43. The long-period tides, shown in §§ 28, 29 of this supplement, that is to say, the lunar monthly (elliptic), the lunar fortnightly (declinational), the solar annual, and the solar semiannual, were calculated in consequence of the astronomical anticipation of the existence of such tides indicated in the general schedule of § 2 of the first Report. There is a mistake in the argument printed for the lunar monthly, which has been pointed out to me by Mr. Roberts. It ought to be $(\sigma-\varpi)\,t$, instead of $\sigma\,t$. The error produces scarcely a sensible influence on the calculations which have been made, and it is easily allowed for.

44. The "luni-solar fortnightly shallow-water (synodic) tide" is a tide the existence of which was suggested by Helmholtz's theory of compound sounds (§§ 24, 25 of first Report). The harmonic analysis consequently applied to discover it has proved it to be very sensible both at Ramsgate and Liverpool; and has shown that in each station it gives highest average level at the times of neap-tides, and lowest average at the times of spring-tides. Its amount for Ramsgate (§ 28) is a tenth of a foot above and below the mean level. Its amount at Liverpool is rather less, being only seven-hundredths of a foot above and below mean level, as will be seen later.

45. It will be seen that the lunar declinational fortnightly and the solar (declinational or meteorological) semiannual present no agreement with astronomical theory. The solar is of more than twice the amount of the lunar. The lunar is so small that it may be merely a result of errors of the tide-gauge. The solar semiannual (seven-hundredths of a foot above and below mean level) giving highest average level Feb. 14 and Aug. 15, seems too large to be not genuine; but it cannot be astronomical, or there would be a corresponding lunar tide.

46. The solar annual (referred to in § 10), as shown by the calculations, (Ramsgate, year 1864, being ·13 of a foot above and below mean), is certainly much too large to be attributable to the eccentricity of the earth's orbit, and the time of its maximum (Sept. 21) does not at all suit the astronomical theory. Its origin (as well as that of the semiannual?) is in all probability meteorological. The Liverpool observations for 1857–58 show a greater difference (·36 of a foot above and below mean level); and time of maximum average height, Oct. 20.

Progress after date of Mr. Roberts's Supplementary Report.

47. The deduction of the lunar and solar semidiurnal and diurnal tides from the Fiji observations (§§ 26, 38), which is no doubt practicable, is a mathematical problem of considerable interest. A good deal of work towards it has been performed by Mr. Roberts since the date of the conclusion of his Supplementary Report. The plan followed has been simply a direct application of the method of least squares, as in § 28, and it has been carried out so far as the formation of eleven simple equations for the determination of eleven unknown quantities, viz.:—

1 height of mean level.
4 coefficients for lunar diurnal tides.
2 „ „ solar diurnal tides, corresponding to the time of year when the observations were made.
2 coefficients for lunar semidiurnal tides.
2 „ „ solar semidiurnal tides.

—
11

48. The labour of solving these equations by directly calculating the determinants would be very great; and the obvious method of successive approximations which renders the solution of the equations of § 28 very easy is not obviously applicable in this case, because in this case the equations have not the characteristic property* exhibited in the equations of § 28, that the coefficient of one of the unknown quantities is comparatively large, and the coefficients of all the others small in each equation, so that each of the unknown quantities is approximately determined by one alone of the equations. It is probable that some algebraic artifice will be found to reduce within moderate compass the labour of solving the Fiji and other similar sets of equations, and so give a useful practical character to the harmonic analysis for short series of tidal observations, continued through broken periods. But the most for the Natural History of the Pacific tides that could be expected from the results of so limited a series of observations as that which we have from the Fiji islands is much less than can be had with ease by the method already worked out for Ramsgate, Liverpool, and Bombay, when observations made continuously through long periods are available. Accordingly, on learning from volumes of the United States' Coast Survey, which I received last November, that self-registering tide-gauges had been established by the Government of the United States at various stations both on their East and on their West coasts, I immediately applied, on the part of the Committee, by letter, of date Nov. 19, 1868, to Professor Pierce, Superintendent of the Survey, for a series of trustworthy observations of Pacific Tides. Through his kind compliance with my request a year's tide-heights, taken from the diagrams, executed by a tide-gauge at Fort Point, California, reached me last April, and were immediately put into Mr. Roberts's hands to be reduced on the same plan as that which we have followed for the other stations.

49. Besides the work on these observations, we have had on hand the calculation of additional terms from the Ramsgate 1864, the Bombay, and the Liverpool 1857–58 observations, and the complete harmonic reduction *ab initio* of Liverpool observations for the two following years—all of which is now nearly finished. The ability, industry, and intelligence with which Mr. Roberts has performed the work, and directed assistants, when practicable, have been highly satisfactory; and I trust that the large amount of results obtained in consequence will justify amply the expenditure of labour which it has cost. As some of the most important results have only reached me from Mr. Roberts within the last few days, I have not found it practicable to attempt to put them into a form in which the details could be fully explained to this Meeting. The results† themselves are given complete in the file of letters and tables which accompanies this Report.

* Depending on the condition that the time through which the observations are continued either is approximately one complete period or an integral number of complete periods, or is very great in comparison with the period of each constituent tide.

† They are comprehended in the "statement" by Mr. Roberts which forms part (§§ 54–

The Exeter Report concludes with remarks on:—

I. Retardation of times of spring-tides after new or full moon, and deductions as to retardation of earth's rotation.

II. Diurnal tides (or constituents having approximately 24^h for period).

I. *Times of Spring-tides after Full Moon and New Moon.*

50. Dr. Thomas Young gave earlier than Airy, and probably first of all, the dynamical theory that retardation of times of spring-tides after the times of full and change implies friction. The results now presented by the Committee verify the anticipation that there is much retardation in every sea. A few more years of patient work at harmonic reduction, and some sets of good observations from places in the China seas, Antarctic sea, and Pacific, will afford means of directly estimating the loss of energy from the earth's rotation, and will confirm the evidence which Professor Huxley and the geologists, for whom he speaks, find so hard to accept, that energy is being dissipated too rapidly to leave credible any thing approaching to so great drafts on time as they have been accustomed to make.

II. *Diurnal Tides.*

51. A not hitherto explained characteristic of North-Atlantic stations is absence of diurnal tides large enough to be discovered except by scientific analysis. The diurnal components are very conspicuous in the Bombay and Fort-Point tides, especially the Fort Point. That one of the components of lunar and solar diurnal tides whose argument is γt, is very large for Fort Point. Hence, considering that that component, being partly due to moon and partly to sun, gives a *thoroughly true theoretical method* for comparing the sun's and moon's masses, by using a series of nine years' observations, it will in all probability give a somewhat accurate practical result. As to the magnitudes of the diurnal tides in different localities, it is to be remarked that their smallness on the North-Atlantic coasts is irregular, and has not yet been explained dynamically. Their largeness in the Indian Ocean, the China seas, and the Pacific is regular, but makes the tidal phenomena much more complicated than those we know best. The tides in those seas are commonly designated as "irregular." That designation results from a confusion of terms, "irregular" being used as if synonymous with *complicated*. The truth is that the tides on the European coasts of the Atlantic are *irregularly simple*; those in all other seas are comparatively complicated, but regular and explicable.

[Conclusion of Exeter Report, dated from Largs, Ayrshire, Aug. 21, 1869.]

Report by Sir William Thomson, *with detailed Statement by* Mr. E. Roberts, *of the work performed by him for the Committee since the Meeting at Exeter.*

The College, Glasgow, Sept. 10, 1870.

52. The work performed since the Meeting at Exeter has been mainly directed towards a full scientific analysis of the tides of Liverpool; but it has included also as much as could be reached in the way of analyzing observations on the tides of Kurrachee supplied by Mr. Parkes, and on the tides of Fort Point, California, supplied by the United States' Survey. With reference to the latter, I have just received the following interesting letter from Mr.

70) of the Report presented to the Liverpool Meeting and now printed in continuation of the Exeter Report.

Roberts, with prefixed letter to him from Mr. J. E. Hilgard, of the United States' Survey:—

Mr. J. E. Hilgard *to* Mr. E. Roberts.

"United States' Coast-Survey Office,
Washington, Aug. 12, 1870.

"I take occasion to inform you that the reading off of another year's tidal "observations at Fort Point, by hourly ordinates, is in progress, in pursuance "of your request under date of May 27, and will be sent in a few weeks.

"For our own purposes we have as yet only read off from the traces the "high and low waters, and prefer to use for the general discussion the results "of nineteen years.

"Prof. Thomson at first asked for only one year; the first year proving "fragmentary, we read and sent an additional year. The observations now "in preparation will be pretty complete.

"I shall be much surprised if you can get reliable constants out of even "two complete years. We will endeavour to provide for the reading of the "hourly ordinates for the whole series, and will furnish you copies, if you "find it necessary to have more than the additional year, which we shall "send you soon.

"J. E. Hilgard,
Assistant U. S. Coast Survey."

Mr. E. Roberts *to* Sir William Thomson.

"3 Verulam Buildings, Gray's Inn, W.C.,
September 9, 1870.

"I have received the enclosed [preceding] letter from the U. S. Coast "Survey. I have completed the computation of the hourly heights for "fourteen days for Fort Point, and have compared them with the actual "observations. The agreement is remarkably good, the maximum discre-"pancy not being more than three inches, if the actual mean level for each "day is used, instead of the mean level of the year. The larger differences "shown sometimes, when the annual mean level is reckoned from, are clearly "owing to the abnormal state of the atmosphere at those times. Some of the "elliptic diurnal tides are probably sensible for Fort Point and Kurrachee. "In the computation of the heights for Fort Point the following tides were "omitted,—the whole of the long-period tides, and also the semidiurnal λ "[evection] and μ [variation] and quarter-diurnal M S [Helmholtz luni-solar "quarter-diurnal]. The maximum effect of the latter three does not exceed "0·06 ft. I consider the agreement very satisfactory. I expect to have the "heights for Kurrachee for 29 days completed by Monday, and which I "think will be satisfactory to Mr. Parkes. I have completed those series of "Ramsgate not included in our first Report; the M S (Helmholtz quarter-"diurnal luni-solar) tide is 0·33 ft., which is a little larger than what I "should have expected from the corresponding Liverpool component. At "Fort Point and Kurrachee it is scarcely, if at all, sensible, the analyzed "values for each place not exceeding 0·02 ft. I have made no comparison "for Ramsgate, as the differences will in all probability resemble those of "Liverpool already compared, although not differing to quite so great an "extent.

"Edward Roberts."

The value of the harmonic analysis is illustrated by the doubt which Mr. Hilgard expresses as to the possibility of obtaining trustworthy constants

for Fort Point out of "even two complete years" observations, and the undoubtedly approximate attainment of that result by Mr. Roberts, from one year only, which his letter indicates.

53. The funds at the disposal of the Committee have not sufficed to employ calculators to push forward the work as energetically as the Report to the Exeter Meeting recommended. What has been actually done has been done entirely by Mr. Roberts, with only some slight assistance of a comparatively mechanical kind in the way of preparing tables and forms for calculation.

The following is his own statement of the work done for the Committee:—

§§ 54–70. *Statement by Mr. E. Roberts of work performed by him for the Tides Committee, from the Exeter Meeting till August 6, 1870 (including also the results of the analysis of the second year's observations at Kurrachee, obtained since the Liverpool Meeting).*

54. The diagram sheets of the Liverpool tide-gauge promising to give as good results as can most probably be obtained from any system of self-registration at present in use, were selected for further reduction and analysis. Two years' observations following the year whose results are contained in the Report for 1868, §§ 31–34, have been reduced and analyzed in a similar manner. The results agree very satisfactorily with those of the preceding year. The mean height of the water for the last two years is slightly in excess of that found for the first year. In addition to the six series, S, M, L, N, K & O, already defined, three others, representing the solar diurnal (declinational) tide, whose argument is $(\gamma-2\eta)$, called hereafter for brevity P, and the two components of the solar elliptic semidiurnal tides (R and T), whose arguments are $2\left(\gamma-\frac{1}{2}\eta\right)$ and $2\left(\gamma-\frac{3}{2}\eta\right)$, were also included. The solar elliptic semidiurnal tides require a period of two years for their evaluation, by the method we have hitherto followed. The hour-angle for the commencement of the second year was taken as twelve hours in advance of the hour-angle assumed for the first year. As the two years commenced on the same day of the year, the error involved in this assumption is only 0°·25, a quantity which may be reasonably neglected in the analysis of these tides. A Table extending through one year has therefore been used in the composition of the series, and the years 1857–58 and 1858–59 combined for the determination of one value, and 1858–59 and 1859–60 for another determination.

55. Referring the fictitious stars to their true positions at the commencement of each year, by correcting the *assumed* hour-angles (the same table of hour-angles having been used for the three years) by the difference between the *true* and *assumed* places, and neglecting all terms which are very small and not theoretical tides, we have the following sets of values:—

	1857–58.	1858–59.	1859–60.
A_0	16·7192	16·8208	16·8289
Average inclination of Moon's orbit to Earth's equator.	28° 28′	27° 56′	26° 58′

	Series S.			Series M.		
	1857–58.	1858–59.	1859–60.	1857–58.	1858–59.	1859–60.
R_1	0·0453	0·0696	0·0844	0·0192	0·0626	0·0092
ϵ_1	69°·93	59°·78	56°·55	332°·19	266°·69	77°·27
R_2	3·2149	3·3124	3·1938	9·6745	9·8124	9·8930
ϵ_2	11°·78	11°·12	10°·08	326°·10	325°·45	323°·99
R_3	......	......	......	0·1053	0·0984	0·1525
ϵ_3	......	......	......	330°·60	315°·04	321°·71
R_4	0·0612	0·0600	0·0476	0·6847	0·6573	0·6371
ϵ_4	322°·23	330°·18	294°·73	220°·34	217°·68	221°·30
R_6	......	......	......	0·1812	0·1887	0·2093
ϵ_6	......	......	......	342°·76	348°·21	343°·17
R_8	......	......	......	0·0582	0·0808	0·0658
ϵ_8	......	......	......	262°·38	278°·17	259°·39

	Series L.			Series N.		
	1857–58.	1858–59.	1859–60.	1857–58.	1858–59.	1859–60.
R_2	0·5069	0·7849	0·3459	1·8608	1·7607	1·9716
ϵ_2	157°·93	168°·91	144°·51	303°·52	308°·72	303°·98

	Series K.		
	1857–58.	1858–59.	1859–60.
R_1	0·3930	0·3978	0·3853
ϵ_1	283°·95	283°·08	273°·18
R_2	1·1850	1·2742	1·0995
ϵ_2	5°·98	0°·40	349°·61

	Series O.			Series P.		
	1857–58.	1858–59.	1859–60.	1857–58.	1858–59.	1859–60.
R_1	0·4410	0·4136	0·4519	0·1250	0·1339	0·1306
ϵ_1	316°·69	316°·28	318°·81	101°·96	105°·75	98°·61

	Series R.		Series T.	
	1857–58 & 1858–59.	1858–59 & 1859–60.	1857–58 & 1858–59.	1858–59 & 1859–60.
R_2	0·1006	0·0818	0·3490	0·1208
ϵ_2	146°·45	146°·60	67°·97	36°·78

There were very sensible values of A_4, B_4 of series L for all years, and also of A_2, B_2 of series O; but the resulting amplitudes and corrected epochs did not agree, showing (as theory gives) no tides of these periods. The cause of the apparent irregularities of series L is probably satisfactorily explained hereafter.

56. Shortly before the Meeting of the British Association at Exeter in 1869, application was made to Graham H. Hills, Esq., for a Liverpool Tide Diagram-sheet containing curves influenced by a minimum amount of irregularity due to wind, atmospheric pressure, temperature, &c., and which might be taken as practically representing the astronomical tide-curve. Through his kindness a sheet containing a period of thirteen days (1869, April 24th to May 6th) was received, and has proved of great value as a practical test of results and (§§ 61–63) demonstration of new tide-compo-

nents. Meteorological indications were also forwarded by J. Hartnup, Esq., F.R.A.S., of the Observatory, Birkenhead, for the same period.

57. Tables of the foregoing nine series of analyzed tide-components were made, giving the heights due to each, and were computed for every few degrees of hour-angle. On account of the magnitude and quick variation of its tide-components, the M series was computed for every degree of hour-angle, which allowed the interpolation for the fraction of the degree of hour-angle to be done with very little labour. All terms involving multiples of the same hour-angle were included in each Table; thus the M Table contained the heights due to R_1, R_2, R_3, R_4, R_6, and R_8, and the S Table those due to R_1, R_2, and R_4. The K Table contained the heights due to R_1 and R_2. The tide-components affected by the variation of the inclination of the moon's orbit were corrected according to the equilibrium theory. The tide-components so affected are the lunar semidiurnal (R_2 of M series), the lunar diurnal declinational (R_1 of O series), and the lunar and solar diurnal and semidiurnal (R_1 and R_2 of K series). The first was thus presumed to vary as the square of the cosine of the inclination of the moon's orbit to the earth's equator, and the other three as the square of the sine, assuming in the case of the combined lunar and solar tides (K) that the ratio of the tide-generating forces of the moon and sun were as 2 to 1. It was supposed that these assumptions would represent these tides very fairly. The zero of reckoning of the lunar diurnal (declinational) tide was also corrected for, on account of the retrogression of the moon's node causing an oscillation on the earth's equator, of the intersection of this plane with the plane of the moon's orbit. The zero of the K tides is similarly affected; but as these are combined tides, the zero was assumed to be nearer the intersection of the lunar orbit than that of the solar in the ratio of the analyzed semidiurnal lunar and solar tides (3 to 1). This inequality can be included in the regular analysis by introducing terms involving the period of the revolution of the moon's nodes, and requiring a series of observations extending through a period (about eighteen years) of their revolution for the evaluation of the tide-components.

58. In order to eliminate signs in the Tables (which greatly facilitates the summation of the different tide-values in the computation of the tide-height at any moment), the amplitude of each tide has been added, throughout each Table, to the calculated heights for the stated hour-angles. An example of each kind of Table is here given, from which will be more readily understood what has been done. The following represent the values of the height (h) of the tide, being the smaller component (L) of the elliptic semidiurnal tide, due to the revolution of the moon's perigee. The heights are computed for every ten degrees of hour-angle (H.A.). The first Table gives the height as computed from the formula $h = R_2 \cos(2nt - \epsilon_2) = 0{\cdot}56 \text{ ft.} \times \cos(2nt - 148^\circ{\cdot}85)$. In the second the value of R_2 has been added to each value of h. The limits of the first Table are $+R_2$ and $-R_2$, and in the second $2R_2$ and 0.

nt or *H.A.*		*h* ft.	*nt* or *H.A.*	
0	180	−0·48+	90	270
10	190	0·35	100	280
20	200	−0·18+	110	290
30	210	+0·01−	120	300
40	220	0·20	130	310
50	230	0·37	140	320
60	240	0·49	150	330
70	250	0·55	160	340
80	260	0·55	170	350
90	270	+0·48−	180	360

nt or *H.A.*		*h* ft.	*nt* or *H.A.*		*h* ft.
0	180	0·08	90	270	1·04
10	190	0·21	100	280	0·91
20	200	0·38	110	290	0·74
30	210	0·57	120	300	0·55
40	220	0·76	130	310	0·36
50	230	0·93	140	320	0·19
60	240	1·05	150	330	0·07
70	250	1·11	160	340	0·01
80	260	1·11	170	350	0·01
90	270	1·04	180	360	0·08

In the first Table the values of h represent the height of the tide due to this component, referred to mean sea-level (A_0 of analyzed series); in the second Table they are referred to a fictitious level, R_2 feet (0·56), *below* the mean level. Supposing the value of all the amplitudes of the tide-factors to be so added throughout the whole of the Tables, the resulting correction to the summation of tide-heights found for any time will be $A_0 - \Sigma R$. This method gets rid of all signs and renders the work of the calculator much lighter.

59. The *true* hour-angle of each of the fictitious stars was then found for the commencement of the series of tide-heights proposed to be computed (1869, April 24^d 0^h Greenwich mean time). Leverrier's places of the sun and Hansen's places of the moon have been used throughout these reductions. Each hour-angle was then found in its proper column in the Table of hour-angles formed at the commencement of these reductions, and which can be found within a small fraction of a degree in a Table extending through 369 days. The consecutive hour-angles in the Table will be the correct arguments for the heights for 1869, April 24^d 1^h, 2^h, &c. The height (h) was then taken from each Table in succession, using the true hour-angle as found above for argument. The sum of the nine values of h thus found, together with the correction $A_0 - \Sigma R$, will represent the height of the water above the datum-line at first chosen, neglecting the long-period tides, which for Liverpool (§ 63) were found to be very small. A series of heights for every hour of the day for 13 days was thus formed and compared with the heights taken from the diagram-sheet (§ 56), and the differences taken. The average discrepancy was about $\frac{4}{10}$ foot and the maximum 2 feet. The differences showed considerable regularity of disagreement; and it appeared probable that the tide-components, varying with the inclination of the moon's orbit, did not vary strictly according to the law of the equilibrium theory. It was thought advisable to reduce another year for the determination of the law of change, and a period of 369^d 3^h, commencing 1866, January 23^d 0^h, was chosen for this purpose. This period gave very nearly a minimum inclination of moon's orbit to earth's equator, whilst the first year (1857–58) gave nearly a maximum value. The results of the declinational tide-factors obtained from the analysis of this year were not very different from what would have been obtained from the values for the previous years according to the equilibrium theory, but nevertheless indicated that these tides varied to a less extent than what that theory gave.

60. The results for Liverpool for 1866–67 are as follows:—

$A_0 = 16·8998$. Average inclination of Moon's orbit to Earth's equator $= 18° 21'$.

	S	M	L	N	K	O	P
R_1	0·0470	0·0396	......	......	0·3278	0·3058	0·1409
ϵ_1	39°·04	358°·02	......	......	281°·60	312°·74	88°·43
R_2	3·1304	10·2713	0·6015	2·1608	0·6336	......	......
ϵ_2	11°·63	325°·55	124°·08	301°·59	9°·03	......	......
R_3	......	0·0862	......	......	......	......	......
ϵ_3	......	335°·27	......	......	......	......	......
R_4	0·0475	0·7648	......	......	......	......	......
ϵ_4	314°·32	224°·19	......	......	......	......	......
R_6	......	0·2057	......	......	......	......	......
ϵ_6	......	343°·80	......	......	......	......	......
R_8	......	0·0667	......	......	......	......	......
ϵ_8	......	282°·09	......	......	......	......	......

This year's results were incorporated with the previous three years and new tables, using average values, formed, and the heights recomputed and again compared with a similar although somewhat improved result to what had before been obtained.

61. It appearing probable that a closer approximation to the movement of the moon than what is given by a mean motion, including the motion of her perigee, would give a closer agreement between the actual and the calculated heights, it was thought advisable to extend the schedule of arguments (§ 2). Accordingly the terms depending on the two next largest perturbations of the moon (the *evection* and *variation* corrections) have been included. The arguments of the components for the *evection* semidiurnal tide are $2(\gamma-\frac{1}{2}\sigma+\frac{1}{2}\varpi-\eta)$ and $2(\gamma-\frac{3}{2}\sigma-\frac{1}{2}\varpi+\eta)$, and for the *variation* semidiurnal tides $2(\gamma-\eta)$ and $2(\gamma-2\sigma+\eta)$. One of the components of the *variation* tide, having the same period as the solar semidiurnal, is necessarily included in the results of the analysis which we have performed for the latter. Our new terms are therefore reduced to three. Series of hour-angles of these arguments (named for brevity λ, ν, and μ) have been formed and added to our Table. The period chosen for the λ and ν series was $349^d\ 22^h$, and for the μ series $369^d\ 3^h$, each period eliminating in the summation of each the effect of the lunar semidiurnal tide. The results of the four years' analyses of these tides are:—

λ (evection).

	1857–58.	1858–59.	1859–60.	1866–67.
R_2	0·4091	0·2262	0·1165	0·2369
ϵ_2	141°·68	134°·46	191°·08	175°·95

ν (evection).

	1857–58.	1858–59.	1859–60.	1866–67.
R_2	0·7423	0·6303	0·2841	0·7182
ϵ_2	307°·91	284°·01	261°·09	278°·43

μ (variation).

	1857–58.	1858–59.	1859–60.	1866–67.
R_2	0·2860	0·2259	0·3076	0·2561
ϵ_2	31·°72	42°·04	32°·55	32°·42

62. Tables of these components have been formed, and the heights due to each added to the height of the sum of the original nine tide-factors, $A_0-\Sigma R$ having been corrected, and the differences again taken. These differences showed clearly four distinct maxima and minima for each day; and it appeared highly probable that the (Helmholtz) compound luni-solar tide of period $2(2\gamma-\sigma-\eta)$ mentioned in § 24 was of considerable value for Liverpool. The differences having been grouped according to hours of this length (hereafter termed M S), its existence was placed beyond doubt. The four years' observations have been analyzed for its estimation with the following results:—

M S.

	1857–58.	1858–59.	1859–60.	1866–67.
R_4	0·4379	0·3488	0·3879	0·4635
ϵ_4	270°·68	265°·86	270°·49	269°·45

There was a sensible value for A_2, B_2 in each of the above series. The comparative largeness of A_4, B_4 of Series L for Ramsgate, § 23, and for Liverpool, § 37, is probably due to this luni-solar quarter-diurnal tide, the period

of each being nearly of the same value. This component has been included in the calculations of the actual heights.

63. The above four years' observations have been analyzed for the long-period tides, but the resulting amplitudes were very small; and there was so little agreement between the epochs as deduced from the several years, that they were deemed not satisfactorily evaluated. The solar annual tide, however, gave a moderate agreement, the mean value for the four years being 0·36 foot, and the epoch 238°·5, which places its maximum about November 19; but this is probably due in the main to meteorological causes. The differences between the calculated and actual heights, after being corrected for the quarter-diurnal luni-solar tide, also showed that the synodic fortnightly tide of period $2(\sigma-\eta)$ is of sensible value; and the present non-agreement between the analyzed values of the four years may be owing to the influence of wind, barometric disturbance, and also of instrumental errors extending over considerable periods, and seriously affecting the daily means which are the basis of reduction for the long-period tides. If the purified daily means had been corrected for barometer &c., as in the discussion of the Port-Leopold tide observations by Capt. Sir J. C. Ross (Phil. Trans. 1854), it is very probable that more satisfactory results would have been obtained. The following are the results for the Long-period Tides:—

		$(\sigma-\varpi)$	2σ	$2(\sigma-\eta)$	η	2η
1857–58.	R	0·046	0·093	0·068	0·359	0·090
	ϵ	289°·4	170°·7	111°·8	209°·6	144°·1
1858–59.	R	0·198	0·037	0·020	0·284	0·104
	ϵ	31°·6	148°·8	325°·5	258°·7	269°·6
1859–60.	R	0·152	0·024	0·079	0·353	0·190
	ϵ	172°·8	72°·9	303°·4	213°·4	112°·3
1866–67.	R	0·072	0·036	0·053	0·452	0·185
	ϵ	259°·8	340°·6	67°·9	272°·3	228°·7

64. The retardation of the phase of spring-tides is determined by dividing the difference between the epochs of the mean solar and mean lunar semi-diurnal tides (ϵ_2 of series S and M respectively) by twice the daily difference between the mean motions of the moon and sun. Taking the average of epochs for the four years, we have

$$\frac{11°·15-325°·27}{2\times 12°·191}=\frac{45°·88}{24°·382}=1^{d}·882=1^{d}\,21^{h}\,10^{m} \text{ (after moon's syzygies)};$$

similarly the coincidence of phase of the declinational diurnal tides (P and O) is (applying the proper correction to ϵ_1 of series O)

$$\frac{98°·69-311°·97}{2\times 12°·191}=\frac{146°·72}{24°·382}=6^{d}·018=6^{d}\,0^{h}\,26^{m} \text{ (after moon's syzygies)}.$$

Taking the mean of the epochs of each of the tide-components as determined by the analysis of the four years' observations, and expressing each mean value thus obtained in *mean solar time*, we have the following Table of values for Liverpool:—

	S	R	T	M	L	N	MS
	h m	h m	h m	h m	h m	h m	h m
ϵ_1	3 45·3	......	......	......	......	......	......
ϵ_2	0 22·3	4 52·7	1 44·9	11 13·3	5 2·5	10 42·3	......
ϵ_3	......	......	......	7 29·4	......	......	......
ϵ_4	5 15·4	......	......	3 48·6	......	......	4 33·8
ϵ_6	......	......	......	3 57·7	......	......	......
ϵ_8	......	......	......	2 20·0	......	......	......

	K	O	P	λ	ν	μ
	h m	h m	h m	h m	h m	h m
ϵ_1	18 38·7	22 40·4	6 35·8	......	......	......
ϵ_2	0 2·5	......	......	5 27·5	9 55·2	1 14·4

A comparison between the calculated and recorded heights for Liverpool is appended (§ 68).

65. The Ramsgate observations for 1864 have again been taken up, and the value of the tide-components for the series not included in the Report for 1868 have been calculated. The whole is here given, and the epochs have been corrected and are reckoned from the *true* hour-angles of each.

Yr. 1864. A = 10·1988 ft. Average inclination of moon's orbit to earth's equator = 20°·30.

	S	M	L	N	MS
R_1	0·0373	......	......	......	......
ϵ_1	313°·48	......	......	......	......
R_2	1·8772	6·3078	0·3856	1·1126	......
ϵ_2	32°·70	339°·43	186°·28	310°·31	......
R_3	......	0·0448	......	......	......
ϵ_3	......	53°·39	......	......	......
R_4	0·0315	0·5771	......	......	0·3332
ϵ_4	4°·19	240°·27	......	......	125°·35
R_6	0·0268	0·1771	......	......	......
ϵ_6	27°·04	122°·00	......	......	......
R_8	......	0·0599	......	......	......
ϵ_8	......	48°·34	......	......	......

	K	O	P	λ	ν	μ
R_1	0·2070	0·3008	0·0730	......	......	......
ϵ_1	100°·75	99°·34	262°·58	......	......	......
R_2	0·4279	......	......	0·1785	0·3526	0·2639
ϵ_2	10°·55	......	......	169°·97	328°·05	83°·79

Long-period Tides.

	$(\sigma-\varpi)$	2σ	$2(\sigma-\eta)$	η	2η
R	0·0316	0·0331	0·0960	0·1270	0·0748
ϵ	45°·09	268°·29	207°·85	180°·97	288°·02

Retardation of phase of Spring-tides $2^d\ 4^h\ 24^m$ } after moon's syzygies.
Coincidence of phase of Declinational tides $6^d\ 16^h\ 40^m$ }

66. Through the kindness of Prof. Peirce of the U. S. Coast Survey a series of tide observations, taken at Fort Point, San Francisco Bay, California, from 1858, October 1, to 1859, September 30, has been received and thoroughly analyzed. The epochs are referred to *true* hour-angles.

Yr. 1858–59. $A_0 = 8{\cdot}7103$ ft. Average inclination of moon's orbit to earth's equator $= 28^\circ{\cdot}0$

	S	M	K	O	P	MS
R_1	0·0146	0·0539	1·3370	0·8917	0·3672	......
ϵ_1	211°·96	46°·30	192°·17	3°·39	16°·52	......
R_2	0·4067	1·6694	0·1759	......	......	......
ϵ_2	334°·24	330°·81	326°·65	......	......	......
R_3	......	very	......	......	......	......
ϵ_3	......	small.	......	......	......	......
R_4	very	0·0616	......	......	......	0·0248
ϵ_4	small.	23°·32	......	......	......	22°·33

	L	N	λ	ν	μ
R_2	0·0591	0·3931	0·0372	0·1044	0·0257
ϵ_2	102°·63	303°·46	188°·30	287°·23	254°·34

Long-period Tides.

	$(\sigma-\varpi)$	2σ	$2(\sigma-\eta)$	η	2η
R	0·0093	0·0586	0·0183	0·2119	0·2244
ϵ	169°·9	145°·3	211°·0	37°·0	201°·4

Retardation of phase of Spring-tides $0^d\ 3^h\ 23^m$ } after moon's syzygies.
Coincidence of phase of Declinational tides $0^d\ 12^h\ 55^m$ }

A comparison between the calculated and recorded heights for Fort Point is appended (§ 69).

67. A series of tide observations extending through two years, commencing 1868, May 1, taken by the Manora self-registering tide-gauge at Kurrachee, has been received from W. Parkes, Esq., M. Inst. C.E.; and the following series have been analyzed for each year separately, with the exception of the solar elliptic semidiurnal tides (Series R and T), for which the tide-components have been evaluated from the two years combined. The epochs are referred to *true* hour-angles. The datum-line is 2 feet *below* the datum-line of the diagram-sheets.

Yr. 1868–69. $A_0 = 7{\cdot}1488$ ft. Average inclination of moon's orbit to earth's equator $= 19^\circ{\cdot}63$.

	S	M	L	N	MS
R_1	0·0718	......	......	......	......
ϵ_1	176°·57	......	......	......	......
R_2	0·9323	2·5859	0·0804	0·6221	......
ϵ_2	322°·72	295°·78	108°·67	280°·31	......
R_3	......	0·0439	......	......	......
ϵ_3	......	335°·18	......	......	......
R_4	very	0·0169	......	......	0·0173
ϵ_4	small.	47°·04	......	......	216°·79
R_6	......	0·0444	......	......	......
ϵ_6	......	225°·91	......	......	......

	K	O	P	λ	ν	μ
R_1	1·1669	0·5688	0·3755	......	......	......
ϵ_1	142°·87	308°·87	316°·35	......	......	......
R_2	0·2389	......	......	0·0613	0·1955	0·0703
ϵ_2	340°·25	......	......	156°·46	255°·63	269°·99

Long-period Tides.

	$(\sigma-\varpi)$	2σ	$2(\sigma-\eta)$	η	2η
R	0·076	0·038	0·009	0·115	0·198
ϵ	247°·73	335°·40	326°·19	43°·96	81°·98

Yr. 1869–70. A_0=7·2908 ft. Average inclination of moon's orbit to earth's equator = 21°·18.

	S	M	L	N	MS
R_1	0·0712	......	......	......	......
ϵ_1	187°·50	......	......	......	......
R_2	0·9425	2·4974	0·0365	0·5987	......
ϵ_2	323°·68	297°·24	140°·69	282°·83	......
R_3	......	0·0382	......	......	......
ϵ_3	......	336°·09	......	......	......
	very	0·0284	......	......	0·0236
ϵ_4	small.	30°·41	......	......	181°·30
R_6	......	0·0494	......	......	......
ϵ_6	......	215°·16	......	......	......

	K	O	P	λ	ν	μ
R_1	1·1907	0·5905	0·3850	......	......	......
ϵ_1	144°·73	309°·94	320°·27	......	......	......
R_2	0·2355	......	......	0·0381	0·0832	0·0333
ϵ_2	330°·57	......	......	91°·56	224°·40	227°·72

Years 1868–69 and 1869–70 combined.

	R	T
R_2	0·0353	0·1108
ϵ_2	12°·04	38°·96

The following are the results of two of the elliptic diurnal tide-components, whose arguments (§ 2) are $(\gamma+\sigma-\varpi)$ and $(\gamma-3\sigma+\varpi)$, termed hereafter J and Q. The period chosen for their evaluation was 370^d 5^h. These results have been obtained since the Liverpool Meeting.

	Series J.		Series Q.	
	1868–69.	1869–70.	1868–69.	1869–70.
R_1	0·0800	0·0434	0·1110	0·1100
ϵ_1	178°·58	165°·88	308°·23	320°·34

Retardation of phase of Spring-tides $=1^d{\cdot}095=1^d\ 2^h\ 17^m$ } after moon's syzygies.
Coincidence of phase of Declinational tides $=0^d{\cdot}365=0^d\ 8^h\ 46^m$ }

A comparison between the calculated and recorded heights for Kurrachee is appended (§ 70). A graphic representation of the heights of high and low water, as calculated by the system of harmonic analysis and the method pursued by Mr. Parkes, together with the actual recorded heights for Nov. 1869, also accompanies this Report.

68. The series of hourly tide-heights (1869, April 24 to May 6), calculated for St. George's Pier, Liverpool, referred to above, are here given, and will give a moderately accurate idea of the amount of precision at present arrived at. It must not, however, be forgotten that the recorded heights are not corrected in any respect, and include all instrumental errors &c. The value of the Helmholtz shallow-water quarter-diurnal tide (MS) is given in a separate column, and its effect shown in improving generally the preceding differences.

April 24.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of MS tide, H.	Difference, C+H−R.
	ft.	ft.	ft.	ft.	ft.
0	21·46	21·0	+0·46	−0·29	+0·17
1	16·23	15·6	+0·63	−0·40	+0·23
2	10·70	10·7	0·00	−0·11	−0·11
3	6·27	6·5	−0·23	+0·28	+0·05
4	3·81	3·8	+0·01	+0·40	+0·41
5	4·83	3·9	+0·93	+0·11	+1·04
6	9·54	8·3	+1·24	−0·27	+0·97
7	16·32	16·5	−0·18	−0·40	−0·58
8	22·73	23·7	−0·97	−0·13	−1·10
9	27·59	28·3	−0·71	+0·25	−0·46
10	29·70	30·5	−0·80	+0·40	−0·40
11	28·22	29·0	−0·78	+0·16	−0·62
12	23·93	23·8	+0·13	−0·25	−0·12
13	18·53	17·7	+0·83	−0·41	+0·42
14	12·81	12·7	+0·11	−0·18	−0·07
15	7·72	8·2	−0·48	+0·23	−0·25
16	4·43	4·8	−0·37	+0·41	+0·04
17	4·22	3·6	+0·62	+0·18	+0·80
18	7·83	6·1	+1·73	−0·20	+1·53
19	14·44	12·8	+1·64	−0·41	+1·23
20	21·38	21·1	+0·28	−0·21	+0·07
21	27·12	26·9	+0·22	+0·17	+0·39
22	30·41	30·6	−0·19	+0·41	+0·22
23	30·20	30·6	−0·40	+0·23	−0·17

April 25.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of MS tide, H.	Difference, C+H−R.
	ft.	ft.	ft.	ft.	ft.
0	26·52	26·1	+0·42	−0·14	+0·28
1	21·07	19·8	+1·27	−0·40	+0·87
2	14·85	14·2	+0·65	−0·26	+0·39
3	8·74	9·2	−0·46	+0·14	−0·32
4	4·33	4·8	−0·47	+0·41	−0·06
5	2·43	2·3	+0·13	+0·26	+0·39
6	4·41	2·4	+2·01	−0·12	+1·89
7	10·30	8·7	+1·60	−0·40	+1·20
8	17·86	18·1	−0·24	−0·28	−0·52
9	24·90	25·0	−0·10	+0·09	−0·01
10	29·61	29·6	+0·01	+0·39	+0·40
11	31·12	31·4	−0·28	+0·30	+0·02
12	28·57	28·6	−0·03	−0·06	−0·09
13	23·36	22·1	+1·26	−0·38	+0·88
14	17·07	16·1	+0·97	−0·31	+0·66
15	10·86	10·7	+0·16	+0·06	+0·22
16	5·71	6·2	−0·49	+0·38	−0·11
17	2·78	3·1	−0·32	+0·32	0·00
18	3·58	2·1	+1·48	−0·03	+1·45
19	8·41	5·7	+2·71	−0·37	+2·34
20	15·90	14·5	+1·40	−0·33	+1·07
21	23·36	23·1	+0·26	+0·01	+0·27
22	29·03	28·6	+0·43	+0·36	+0·79
23	31·76	31·7	+0·06	+0·36	+0·42

April 26.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of MS tide, H.	Difference, C+H−R.
0	30·74	30·6	+0·14	+0·02	+0·16
1	25·84	24·9	+0·94	−0·34	+0·60
2	19·52	18·2	+1·32	−0·36	+0·96
3	12·94	12·3	+0·64	−0·02	+0·62
4	7·04	7·6	−0·56	+0·34	−0·22
5	2·93	3·8	−0·87	+0·37	−0·50
6	1·88	1·6	+0·28	+0·05	+0·33
7	5·15	2·9	+2·25	−0·33	+1·92
8	12·03	10·5	+1·53	−0·38	+1·15
9	20·13	20·1	+0·03	−0·08	−0·05
10	26·68	26·6	+0·08	+0·31	+0·39
11	31·19	30·6	+0·59	+0·39	+0·98
12	31·54	31·4	+0·14	+0·11	+0·25
13	27·85	27·0	+0·85	−0·29	+0·56
14	21·73	20·4	+1·33	−0·40	+0·93
15	15·09	14·2	+0·89	−0·10	+0·79
16	8·83	9·3	−0·47	+0·27	−0·20
17	4·14	5·0	−0·86	+0·40	−0·46
18	2·13	2·5	−0·37	+0·14	−0·23
19	4·01	2·3	+1·71	−0·27	+1·44
20	9·97	7·6	+2·37	−0·40	+1·97
21	18·03	17·2	+0·83	−0·16	+0·67
22	25·39	24·9	+0·49	+0·25	+0·74
23	30·52	29·6	+0·92	+0·40	+1·32

April 27.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of MS tide, H.	Difference, C+H−R.
0	32·00	31·9	+0·10	+0·18	+0·28
1	29·50	29·1	+0·40	−0·22	+0·18
2	24·12	22·3	+1·82	−0·41	+1·41
3	17·54	16·5	+1·04	−0·21	+0·83
4	10·99	11·1	−0·11	+0·20	+0·09
5	5·56	6·2	−0·64	+0·41	−0·23
6	2·26	2·9	−0·64	+0·21	−0·43
7	2·45	1·1	+1·35	−0·20	+1·15
8	6·86	4·0	+2·86	−0·41	+2·45
9	14·48	13·1	+1·38	−0·24	+1·14
10	22·51	22·2	+0·31	+0·17	+0·48
11	28·68	27·9	+0·78	+0·41	+1·19
12	31·86	31·2	+0·66	+0·26	+0·92
13	30·90	30·4	+0·50	−0·15	+0·35
14	26·05	25·0	+1·05	−0·40	+0·65
15	19·57	18·6	+0·97	−0·28	+0·69
16	12·92	12·9	+0·02	+0·11	+0·13
17	7·18	8·0	−0·82	+0·40	−0·42
18	3·29	4·2	−0·91	+0·28	−0·63
19	2·43	2·2	+0·23	−0·12	+0·11
20	5·49	3·0	+2·49	−0·40	+2·09
21	12·23	9·8	+2·43	−0·29	+2·14
22	20·32	19·0	+1·32	+0·09	+1·41
23	27·06	26·0	+1·06	+0·39	+1·45

April 28.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of M8 tide, H.	Difference, C+H−R.
	ft.	ft.	ft.	ft.	ft.
0	31·10	30·1	+1·00	+0·32	+1·32
1	31·52	30·9	+0·62	−0·06	+0·56
2	27·89	26·8	+1·09	−0·38	+0·71
3	21·92	20·5	+1·42	−0·33	+1·09
4	15·37	14·6	+0·77	+0·03	+0·80
5	9·41	9·5	−0·09	+0·37	+0·28
6	4·80	5·1	−0·30	+0·34	+0·04
7	2·65	2·4	+0·25	−0·04	+0·21
8	4·04	1·9	+2·14	−0·36	+1·78
9	9·38	7·0	+2·38	−0·35	+2·03
10	17·18	16·1	+1·08	+0·01	+1·09
11	24·56	23·6	+0·96	+0·36	+1·32
12	29·63	28·1	+1·53	+0·37	+1·90
13	31·41	30·2	+1·21	+0·02	+1·23
14	29·17	28·1	+1·07	−0·34	+0·73
15	23·71	22·5	+1·21	−0·38	+0·83
16	17·21	16·5	+0·71	−0·05	+0·66
17	11·17	11·4	−0·23	+0·32	+0·09
18	6·22	6·9	−0·68	+0·38	−0·30
19	3·46	3·8	−0·34	+0·08	−0·26
20	3·91	2·2	+1·71	−0·31	+1·40
21	7·71	5·0	+2·71	−0·39	+2·32
22	14·76	12·6	+2·16	−0·08	+2·08
23	22·29	21·0	+1·29	+0·31	+1·60

April 29.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of M8 tide, H.	Difference, C+H−R.
	ft.	ft.	ft.	ft.	ft.
0	27·91	26·7	+1·21	+0·39	+1·60
1	30·68	29·7	+0·98	+0·11	+1·09
2	29·80	29·1	+0·70	−0·29	+0·41
3	25·53	24·4	+1·13	−0·40	+0·73
4	19·50	18·6	+0·90	−0·13	+0·77
5	13·58	13·4	+0·18	+0·27	+0·45
6	8·46	8·6	−0·14	+0·40	+0·26
7	5·00	5·1	−0·10	+0·16	+0·06
8	4·01	3·1	+0·91	−0·25	+0·66
9	6·36	4·7	+1·66	−0·41	+1·25
10	12·17	11·0	+1·17	−0·16	+1·01
11	19·58	18·9	+0·68	+0·25	+0·93
12	25·84	24·9	+0·94	+0·41	+1·35
13	29·59	28·6	+0·99	+0·18	+1·17
14	29·99	29·1	+0·89	−0·22	+0·67
15	26·78	26·1	+0·68	−0·41	+0·27
16	21·25	20·3	+0·95	−0·21	+0·74
17	15·26	15·1	+0·16	+0·22	+0·38
18	9·98	10·5	−0·52	+0·41	−0·11
19	6·12	6·7	−0·58	+0·21	−0·37
20	4·45	4·3	+0·15	−0·19	−0·04
21	5·62	4·0	+1·62	−0·41	+1·21
22	10·09	8·4	+1·69	−0·24	+1·45
23	16·94	15·6	+1·34	+0·17	+1·51

April 30.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of M8 tide, H.	Difference, C+H−R.
0	23·42	22·8	+0·62	+0·41	+1·03
1	27·77	26·9	+0·87	+0·26	+1·13
2	29·26	28·8	+0·46	−0·14	+0·32
3	27·57	27·2	+0·37	−0·40	−0·03
4	23·01	22·1	+0·91	−0·28	+0·63
5	17·46	17·1	+0·36	+0·11	+0·47
6	12·44	12·4	+0·04	+0·39	+0·43
7	8·61	8·6	+0·01	+0·30	+0·31
8	6·03	5·7	+0·33	−0·09	+0·24
9	5·97	5·0	+0·97	−0·39	+0·58
10	8·88	8·2	+0·68	−0·29	+0·39
11	14·66	14·0	+0·66	+0·09	+0·75
12	21·22	20·6	+0·62	+0·38	+1·00
13	26·18	25·5	+0·68	+0·32	+1·00
14	28·24	28·2	+0·04	−0·06	−0·02
15	28·08	27·8	+0·28	−0·38	−0·10
16	24·50	24·0	+0·50	−0·33	+0·17
17	19·11	18·6	+0·51	+0·03	+0·54
18	13·89	14·4	−0·51	+0·36	−0·15
19	9·69	10·3	−0·61	+0·36	−0·25
20	6·89	7·1	−0·21	−0·01	−0·22
21	6·05	5·3	+0·75	−0·36	+0·39
22	7·75	6·6	+1·15	−0·36	+0·79
23	12·29	11·2	+1·09	−0·02	+1·07

May 1.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of M8 tide, H.	Difference, C+H−R.
0	18·41	17·1	+1·31	+0·34	+1·65
1	23·70	23·0	+0·70	+0·37	+1·07
2	26·75	26·2	+0·55	+0·02	+0·57
3	27·43	27·2	+0·23	−0·33	−0·10
4	25·20	25·2	0·00	−0·38	−0·38
5	20·84	20·4	+0·44	−0·05	+0·39
6	16·09	16·3	−0·21	+0·32	+0·11
7	12·11	12·3	−0·19	+0·39	+0·20
8	9·20	9·2	0·00	+0·08	+0·08
9	7·70	7·1	+0·60	−0·31	+0·29
10	8·16	7·4	+0·76	−0·40	+0·36
11	11·17	10·4	+0·77	−0·10	+0·67
12	16·43	15·7	+0·73	+0·29	+1·02
13	21·87	21·3	+0·57	+0·39	+0·96
14	25·56	25·1	+0·46	+0·11	+0·57
15	27·14	27·1	+0·04	−0·27	−0·23
16	26·05	26·4	−0·35	−0·40	−0·75
17	22·39	22·6	−0·21	−0·13	−0·34
18	17·85	18·2	−0·35	+0·25	−0·10
19	13·42	14·3	−0·88	+0·40	−0·48
20	10·20	10·8	−0·60	+0·16	−0·44
21	8·13	8·2	−0·07	−0·25	−0·32
22	7·81	7·3	+0·51	−0·41	+0·10
23	9·61	8·9	+0·71	−0·18	+0·53

May 2.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of MS tide, H.	Difference, C+H−R.
	ft.	ft.	ft.	ft.	ft.
0	13·72	12·6	+1·12	+0·22	+1·34
1	18·95	17·8	+1·15	+0·41	+1·56
2	23·07	22·2	+0·87	+0·18	+1·05
3	25·32	24·7	+0·62	−0·20	+0·42
4	25·51	25·1	+0·41	−0·41	0·00
5	23·25	23·1	+0·15	−0·21	−0·06
6	19·35	19·1	+0·25	+0·17	+0·42
7	15·58	15·6	−0·02	+0·41	+0·39
8	12·61	12·4	+0·21	+0·23	+0·44
9	10·48	9·9	+0·58	−0·14	+0·44
10	9·45	8·9	+0·55	−0·40	+0·15
11	9·96	9·6	+0·36	−0·26	+0·10
12	12·69	12·1	+0·59	+0·14	+0·73
13	17·23	16·3	+0·93	+0·40	+1·33
14	21·64	20·7	+0·94	+0·28	+1·22
15	24·54	23·7	+0·84	−0·12	+0·72
16	25·59	25·3	+0·29	−0·40	−0·11
17	24·26	24·6	−0·34	−0·28	−0·62
18	20·94	21·6	−0·66	+0·09	−0·57
19	17·04	17·6	−0·56	+0·39	−0·17
20	14·00	14·1	−0·10	+0·30	+0·20
21	11·22	11·3	−0·08	−0·09	−0·17
22	9·64	9·2	+0·44	−0·38	+0·06
23	9·26	8·6	+0·66	−0·31	+0·35

May 3.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of MS tide, H.	Difference, C+H−R.
	ft.	ft.	ft.	ft.	ft.
0	10·74	10·4	+0·34	+0·06	+0·40
1	14·32	13·9	+0·42	+0·38	+0·80
2	18·72	18·3	+0·42	+0·32	+0·74
3	22·07	21·4	+0·67	−0·04	+0·63
4	23·89	23·2	+0·69	−0·37	+0·32
5	23·97	23·3	+0·67	−0·33	+0·34
6	21·91	21·5	+0·41	+0·01	+0·42
7	18·76	18·4	+0·36	+0·36	+0·72
8	15·90	15·5	+0·40	+0·35	+0·75
9	13·63	12·9	+0·73	+0·02	+0·75
10	11·86	11·0	+0·86	−0·34	+0·52
11	10·83	10·1	+0·73	−0·36	+0·37
12	11·07	10·6	+0·47	−0·02	+0·45
13	13·30	12·8	+0·50	+0·32	+0·82
14	17·18	16·5	+0·68	+0·38	+1·06
15	20·96	20·1	+0·86	+0·05	+0·91
16	23·44	22·6	+0·84	−0·33	+0·51
17	24·37	23·8	+0·57	−0·38	+0·19
18	23·28	23·1	+0·18	−0·08	+0·10
19	20·38	20·3	+0·08	+0·31	+0·39
20	17·17	17·0	+0·17	+0·39	+0·56
21	14·55	14·0	+0·55	+0·11	+0·66
22	12·34	11·4	+0·94	−0·29	+0·65
23	10·71	9·6	+1·11	−0·40	+0·71

May 4.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of MS tide, H.	Difference, C+H−R.
0	9·95	9·1	+0·85	−0·11	+0·74
1	11·03	10·4	+0·63	+0·27	+0·90
2	14·10	13·2	+0·90	+0·40	+1·30
3	17·99	17·0	+0·99	+0·14	+1·13
4	21·02	20·1	+0·92	−0·24	+0·68
5	22·84	21·9	+0·94	−0·41	+0·53
6	23·07	22·6	+0·47	−0·14	+0·33
7	21·35	21·5	−0·15	+0·25	+0·10
8	18·93	19·2	−0·27	+0·40	+0·13
9	16·72	16·5	+0·22	+0·18	+0·40
10	14·72	14·0	+0·72	−0·22	+0·50
11	12·87	11·7	+1·17	−0·41	+0·76
12	11·43	10·4	+1·03	−0·21	+0·82
13	11·17	10·5	+0·67	+0·20	+0·87
14	13·09	12·2	+0·89	+0·41	+1·30
15	16·73	15·7	+1·03	+0·21	+1·24
16	20·27	19·3	+0·97	−0·19	+0·78
17	22·73	21·9	+0·83	−0·41	+0·42
18	23·81	23·4	+0·41	−0·24	+0·17
19	23·00	23·2	−0·20	+0·17	−0·03
20	20·59	21·1	−0·51	+0·41	−0·10
21	17·90	17·9	0·00	+0·26	+0·26
22	15·46	15·0	+0·46	−0·14	+0·32
23	13·16	12·6	+0·56	−0·40	+0·16

May 5.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of MS tide, H.	Difference, C+H−R.
0	11·21	10·6	+0·61	−0·27	+0·34
1	9·94	9·6	+0·34	+0·12	+0·46
2	10·54	10·2	+0·34	+0·40	+0·74
3	13·56	12·5	+1·06	+0·29	+1·35
4	17·29	16·1	+1·19	−0·09	+1·10
5	20·41	20·0	+0·41	−0·39	+0·02
6	22·47	22·4	+0·07	−0·29	−0·22
7	23·14	23·6	−0·46	+0·09	−0·37
8	21·74	23·1	−1·36	+0·39	−0·97
9	19·70	20·8	−1·10	+0·32	−0·78
10	17·63	17·8	−0·17	−0·06	−0·23
11	15·42	15·1	+0·32	−0·38	−0·06
12	12·99	12·6	+0·39	−0·33	+0·06
13	11·06	10·9	+0·16	+0·03	+0·19
14	10·51	10·6	−0·09	+0·37	+0·28
15	12·53	11·9	+0·63	+0·34	+0·97
16	16·20	15·1	+1·10	−0·01	+1·09
17	19·88	19·3	+0·58	−0·36	+0·22
18	22·60	22·6	0·00	−0·35	−0·35
19	24·07	24·6	−0·53	+0·01	−0·52
20	23·47	24·6	−1·13	+0·36	−0·77
21	21·29	22·6	−1·31	+0·37	−0·94
22	18·70	19·0	−0·30	+0·02	−0·28
23	16·03	15·9	+0·13	−0·34	−0·21

May 6.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of MS tide, H.	Difference, C+H−R.	Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Value of MS tide, H.	Difference, C+H−R.
	ft.	ft.	ft.	ft.	ft.		ft.	ft.	ft.	ft.	ft.
0	13·11	12·7	+0·41	−0·38	+0·03	12	15·31	15·4	−0·09	−0·40	−0·49
1	10·46	10·4	+0·06	−0·05	+0·01	13	12·28	12·5	−0·22	−0·13	−0·35
2	8·93	9·2	−0·27	+0·32	+0·05	14	9·86	10·6	−0·74	+0·27	−0·47
3	9·79	9·7	+0·09	+0·38	+0·47	15	9·52	10·2	−0·68	+0·40	−0·28
4	13·05	12·3	+0·75	+0·08	+0·83	16	11·93	12·1	−0·17	+0·16	−0·01
5	17·07	16·4	+0·67	−0·31	+0·36	17	16·08	15·9	+0·18	−0·22	−0·04
6	20·45	20·6	−0·15	−0·39	−0·54	18	20·09	20·2	−0·11	−0·41	−0·52
7	22·98	23·8	−0·82	−0·08	−0·90	19	23·11	24·0	−0·89	−0·11	−1·00
8	23·72	25·4	−1·68	+0·31	−1·37	20	24·98	26·1	−1·12	+0·25	−0·87
9	22·60	24·8	−2·20	+0·39	−1·81	21	24·35	26·1	−1·75	+0·41	−1·34
10	21·47	22·1	−0·63	+0·11	−0·52	22	22·04	23·6	−1·56	+0·18	−1·38
11	18·15	18·6	−0·45	−0·29	−0·74	23	19·14	19·6	−0·46	−0·22	−0·68

69. The following is a comparison for fourteen days, commencing 1859, March 16, of the recorded heights at Fort Point, San Francisco Bay, California, with the heights calculated from the analyzed tide-components (§ 66). In the calculation of the heights, the mean level of the water as determined by the observations for the whole year was used. The difference between this mean level and the mean of the twenty-four hourly heights (corrected for all sensible lunar influence) for each day is also given. The effect of this is to greatly improve the differences (C−R). The following tide-components were omitted in the calculations:—the whole of the long-period tides, the luni-solar semidiurnal tides λ and μ, and the Helmholtz shallow-water quarter-diurnal tide MS. The computations are for *local* time.

1859, March 16.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, C−R+ΔA_0.
	ft.	ft.	ft.	ft.	ft.
0	9·03	8·8	+0·23	−0·24	−0·01
1	7·56	7·0	+0·56		+0·32
2	6·26	5·7	+0·56		+0·32
3	5·44	5·0	+0·44		+0·20
4	5·26	5·0	+0·26		+0·02
5	5·72	5·5	+0·22		−0·02
6	6·67	6·5	+0·17		−0·07
7	7·93	7·6	+0·33		+0·09
8	9·27	9·0	+0·27		+0·03
9	10·36	9·9	+0·46		+0·22
10	10·95	10·4	+0·55		+0·31
11	10·92	10·4	+0·52		+0·28
12	10·28	10·0	+0·28		+0·04
13	9·28	9·2	+0·08		−0·16
14	8·25	7·9	+0·35		+0·11
15	7·47	7·2	+0·27		+0·03
16	7·23	7·1	+0·13		−0·11
17	7·49	7·5	−0·01		−0·25
18	8·22	8·3	−0·08		−0·32
19	9·21	9·3	−0·09		−0·33
20	10·23	10·2	+0·03		−0·21
21	11·08	11·1	−0·02		−0·26
22	11·41	11·3	+0·11		−0·13
23	11·13	11·2	−0·07		−0·31

1859, March 17.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, C−R+ΔA_0.
	ft.	ft.	ft.	ft.	ft.
0	10·20	10·2	0·00	−0·11	−0·11
1	8·82	8·6	+0·22		+0·11
2	7·34	7·1	+0·24		+0·13
3	6·15	5·9	+0·25		+0·14
4	5·52	5·4	+0·12		+0·01
5	5·57	5·5	+0·07		−0·04
6	6·24	6·3	−0·06		−0·17
7	7·34	7·4	−0·06		−0·17
8	8·68	8·5	+0·18		+0·07
9	9·95	9·8	+0·15		+0·04
10	10·88	10·6	+0·28		+0·17
11	11·21	11·0	+0·21		+0·10
12	10·87	10·8	+0·07		−0·04
13	9·96	10·0	−0·04		−0·15
14	8·77	8·7	+0·07		−0·04
15	7·62	7·5	+0·12		+0·01
16	6·89	6·8	+0·09		−0·02
17	6·73	6·8	−0·07		−0·18
18	7·18	7·2	−0·02		−0·13
19	8·05	8·2	−0·15		−0·26
20	9·19	9·2	−0·01		−0·12
21	10·26	10·1	+0·16		+0·05
22	11·05	11·0	+0·05		−0·06
23	11·34	11·3	+0·04		−0·07

1859, March 18. / 1859, March 19.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C—R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.	Hour.	Calculated height, C.	Recorded height, R.	Difference, C—R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.		ft.	ft.	ft.	ft.	ft.
0	10·94	10·9	+0·04	0·00	+0·04	0	11·12	10·7	+0·42	−0·16	+0·26
1	9·96	10·0	−0·04		−0·04	1	10·63	10·3	+0·33		+0·17
2	8·59	8·5	+0·09		+0·09	2	9·63	9·5	+0·13		−0·03
3	7·22	7·1	+0·12		+0·12	3	8·35	8·2	+0·15		−0·01
4	6·20	6·2	0·00		0·00	4	7·18	7·0	+0·18		+0·02
5	5·82	5·9	−0·08		−0·08	5	6·42	6·4	+0·02		−0·14
6	6·11	6·3	−0·19		−0·19	6	6·34	6·4	−0·06		−0·22
7	6·93	7·1	−0·17		−0·17	7	6·82	7·0	−0·18		−0·34
8	8·15	8·3	−0·15		−0·15	8	7·79	7·9	−0·11		−0·27
9	9·46	9·4	+0·06		+0·06	9	8·98	9·0	−0·02		−0·18
10	10·57	10·5	+0·07		+0·07	10	10·13	10·2	−0·07		−0·23
11	11·24	11·0	+0·24		+0·24	11	11·01	10·8	+0·21		+0·05
12	11·27	11·1	+0·17		+0·17	12	11·38	11·2	+0·18		+0·02
13	10·61	10·5	+0·11		+0·11	13	11·09	11·1	−0·01		−0·17
14	9·48	9·4	+0·08		+0·08	14	10·21	10·2	+0·01		−0·15
15	8·14	7·9	+0·24		+0·24	15	8·92	8·9	+0·02		−0·14
16	6·99	6·8	+0·19		+0·19	16	7·55	7·4	+0·15		−0·01
17	6·39	6·2	+0·19		+0·19	17	6·52	6·4	+0·12		−0·04
18	6·40	6·2	+0·20		+0·20	18	6·04	5·9	+0·14		−0·02
19	6·99	6·8	+0·19		+0·19	19	6·22	6·1	+0·12		−0·04
20	7·98	7·7	+0·28		+0·28	20	6·90	6·7	+0·20		+0·04
21	9·13	8·7	+0·43		+0·43	21	7·93	7·7	+0·23		+0·07
22	10·21	9·8	+0·41		+0·41	22	9·07	8·7	+0·37		+0·21
23	10·95	10·4	+0·55		+0·55	23	10·07	9·8	+0·27		+0·11

1859, March 20. / 1859, March 21.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C—R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.	Hour.	Calculated height, C.	Recorded height, R.	Difference, C—R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
0	10·67	10·4	+0·27	+0·05	+0·32	0	9·78	9·7	+0·08	+0·37	+0·45
1	10·76	10·6	+0·16		+0·21	1	10·32	10·3	+0·02		+0·39
2	10·26	10·3	−0·04		+0·01	2	10·35	10·5	−0·15		+0·22
3	9 32	9·5	−0·18		−0·13	3	9·91	10·2	−0·29		+0·08
4	8·23	8·4	−0·17		−0·12	4	9·10	9·5	−0·40		−0·03
5	7·34	7·5	−0·16		−0·11	5	8·27	8·8	−0·53		−0·16
6	6·88	7·1	−0·22		−0·17	6	7·65	8·1	−0·45		−0·08
7	7·01	7·4	−0·39		−0·34	7	7·45	8·0	−0·55		−0·18
8	7·63	8·2	−0·57		−0·52	8	7·75	8·3	−0·55		−0·18
9	8·62	9·1	−0·48		−0·43	9	8·48	9·1	−0·62		−0·25
10	9·70	10·1	−0·40		−0·35	10	9·33	9·8	−0·47		−0·10
11	10·64	11·1	−0·46		−0·41	11	10·23	10·8	−0·57		−0·20
12	11·24	11·8	−0·56		−0·51	12	10·95	11·5	−0·55		−0·18
13	11·30	12·0	−0·70		−0·65	13	11·25	11·9	−0·65		−0·28
14	10·78	11·5	−0·72		−0·67	14	11·06	11·7	−0·64		−0·27
15	9·71	10·3	−0·59		−0·54	15	10·38	10·8	−0·42		−0·05
16	8·37	8·7	−0·33		−0·28	16	9·21	9·6	−0·39		−0·02
17	7·10	7·3	−0·20		−0·15	17	7·91	8·1	−0·19		+0·18
18	6·18	6·5	−0·32		−0·27	18	6·75	6·9	−0·15		+0·22
19	5·89	6·2	−0·31		−0·26	19	6·03	6·1	−0·07		+0·30
20	6·14	6·4	−0·26		−0·21	20	5·81	5·9	−0·09		+0·28
21	6·86	7·0	−0·14		−0·09	21	6·14	6·1	+0·04		+0·41
22	7·87	7·9	−0·03		+0·02	22	6·83	6·7	+0·13		+0·50
23	8·92	8·8	+0·12		+0·17	23	7·76	7·5	+0·26		+0·63

1859, March 22.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.
0	8·66	8·4	+0·26	+0·13	+0·39
1	9·44	9·2	+0·24		+0·37
2	9·90	9·7	+0·20		+0·33
3	9·96	9·9	+0·06		+0·19
4	9·64	9·6	+0·04		+0·17
5	9·05	9·2	−0·15		−0·02
6	8·45	8·7	−0·25		−0·12
7	8·12	8·2	−0·08		+0·05
8	8·11	8·3	−0·19		−0·06
9	8·49	8·7	−0·21		−0·08
10	9·14	9·3	−0·16		−0·03
11	9·88	10·0	−0·12		+0·01
12	10·55	10·6	−0·05		+0·08
13	11·00	11·2	−0·20		−0·07
14	11·07	11·3	−0·23		−0·10
15	10·75	10·9	−0·15		−0·02
16	9·96	10·0	−0·04		+0·09
17	8·83	8·7	+0·13		+0·26
18	7·61	7·4	+0·21		+0·34
19	6·60	6·4	+0·20		+0·33
20	6·00	5·9	+0·10		+0·23
21	5·82	5·7	+0·12		+0·25
22	6·15	6·0	+0·15		+0·28
23	6·77	6·6	+0·17		+0·30

1859, March 23.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.
0	7·56	7·4	+0·16	−0·05	+0·11
1	8·37	8·2	+0·17		+0·12
2	9·05	9·0	+0·05		0·00
3	9·52	9·4	+0·12		+0·07
4	9·67	9·5	+0·17		+0·12
5	9·51	9·4	+0·11		+0·06
6	9·14	9·1	+0·04		−0·01
7	8·78	8·8	−0·02		−0·07
8	8·59	8·7	−0·11		−0·16
9	8·74	8·7	+0·04		−0·01
10	9·10	9·1	0·00		−0·05
11	9·64	9·5	+0·14		+0·09
12	10·19	10·0	+0·19		+0·14
13	10·64	10·5	+0·14		+0·09
14	10·87	10·9	−0·03		−0·08
15	10·84	10·9	−0·06		−0·11
16	10·39	10·5	−0·11		−0·16
17	9·62	9·5	+0·12		+0·07
18	8·57	8·3	+0·27		+0·22
19	7·50	7·2	+0·30		+0·25
20	6·54	6·3	+0·24		+0·19
21	6·07	5·8	+0·27		+0·22
22	5·90	5·8	+0·10		+0·05
23	6·13	6·1	+0·03		−0·02

1859, March 24.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
0	6·65	6·6	+0·05	−0·11	−0·06
1	7·34	7·3	+0·04		−0·07
2	8·08	8·0	+0·08		−0·03
3	8·76	8·6	+0·16		+0·05
4	9·28	9·1	+0·18		+0·07
5	9·55	9·3	+0·25		+0·14
6	9·54	9·4	+0·14		+0·03
7	9·33	9·3	+0·03		−0·08
8	9·12	9·1	+0·02		−0·09
9	9·07	9·0	+0·07		−0·04
10	9·17	9·1	+0·07		−0·04
11	9·47	9·3	+0·17		+0·06
12	9·89	9·6	+0·29		+0·18
13	10·26	10·0	+0·26		+0·15
14	10·56	10·3	+0·26		+0·15
15	10·68	10·5	+0·18		+0·07
16	10·57	10·5	+0·07		−0·04
17	10·17	10·1	+0·07		−0·04
18	9·43	9·3	+0·13		+0·02
19	8·48	8·2	+0·28		+0·17
20	7·47	7·1	+0·37		+0·26
21	6·63	6·4	+0·23		+0·12
22	6·09	6·0	+0·09		−0·02
23	5·93	6·0	−0·07		−0·18

1859, March 25.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
0	6·10	6·2	−0·10	−0·06	−0·16
1	6·53	6·6	−0·07		−0·13
2	7·15	7·3	−0·15		−0·21
3	7·88	8·0	−0·12		−0·18
4	8·60	8·7	−0·10		−0·16
5	9·21	9·2	+0·01		−0·05
6	9·58	9·5	+0·08		+0·02
7	9·67	9·7	−0·03		−0·09
8	9·58	9·6	−0·02		−0·08
9	9·44	9·5	−0·06		−0·12
10	9·36	9·3	+0·06		0·00
11	9·47	9·4	+0·07		+0·01
12	9·64	9·5	+0·14		+0·08
13	9·89	9·8	+0·09		+0·03
14	10·15	10·0	+0·15		+0·09
15	10·34	10·3	+0·04		−0·02
16	10·45	10·5	−0·05		−0·11
17	10·39	10·4	−0·01		−0·07
18	10·01	10·1	−0·09		−0·15
19	9·36	9·5	−0·14		−0·20
20	8·48	8·5	−0·02		−0·08
21	7·50	7·6	−0·10		−0·16
22	6·68	6·8	−0·12		−0·18
23	6·14	6·4	−0·26		−0·32

1859, March 26.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, C−R+ΔA_0.
	ft.	ft.	ft.	ft.	ft.
0	5·95	6·4	−0·45	+0·16	−0·29
1	6·04	6·5	−0·46		−0·30
2	6·45	6·9	−0·45		−0·29
3	7·06	7·5	−0·44		−0·28
4	7·83	8·2	−0·37		−0·21
5	8·64	8·9	−0·26		−0·10
6	9·30	9·4	−0·10		+0·06
7	9·76	9·8	−0·04		+0·12
8	9·87	10·0	−0·13		+0·03
9	9·78	10·0	−0·22		−0·06
10	9·56	9·8	−0·24		−0·08
11	9·44	9·5	−0·06		+0·10
12	9·42	9·4	+0·02		+0·18
13	9·54	9·4	+0·14		+0·30
14	9·71	9·7	+0·01		+0·17
15	9·92	10·0	−0·08		+0·08
16	10·13	10·2	−0·07		+0·09
17	10·31	10·4	−0·09		+0·07
18	10·32	10·4	−0·08		+0·08
19	10·03	10·2	−0·17		−0·01
20	9·40	9·5	−0·10		+0·06
21	8·48	8·8	−0·32		−0·16
22	7·55	7·9	−0·35		−0·19
23	6·70	7·0	−0·30		−0·14

1859, March 27*.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, C−R+ΔA_0.
	ft.	ft.	ft.	ft.	ft.
0	6·14	6·5	−0·36	+0·13	−0·23
1	5·97	6·4	−0·43		−0·30
2	6·02	6·6	−0·58		−0·45
3	6·47	6·9	−0·43		−0·30
4	7·15	7·6	−0·45		−0·32
5	8·02	8·2	−0·18		−0·05
6	8·90	8·9	0·00		+0·13
7	9·58	9·4	+0·18		+0·31
8	10·00	9·7	+0·30		+0·43
9	10·02	9·8	+0·22		+0·35
10	9·82	9·6	+0·22		+0·35
11	9·50	9·3	+0·20		+0·33
12	9·26	8·9	+0·36		+0·49
13	9·16	8·6	+0·56		+0·69
14	9·23	8·6	+0·63		+0·76
15	9·39	8·8	+0·59		+0·72
16	9·68	9·1	+0·58		+0·71
17	10·00	9·4	+0·60		+0·73
18	10·27	9·6	+0·67		+0·80
19	10·34	9·7	+0·64		+0·77
20	10·07	9·5	+0·57		+0·70
21	9·42	8·9	+0·52		+0·65
22	8·52	8·1	+0·42		+0·55
23	7·52	7·1	+0·42		+0·55

1859, March 28.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, C−R+ΔA_0.
0	6·67	6·1	+0·57	−0·54	+0·03
1	6·14	5·7	+0·44		−0·10
2	5·96	5·7	+0·26		−0·28
3	6·14	5·8	+0·34		−0·20
4	6·68	6·3	+0·38		−0·16
5	7·49	7·0	+0·49		−0·05
6	8·43	7·9	+0·53		−0·01
7	9·30	8·6	+0·70		+0·16
8	9·93	9·1	+0·83		+0·29
9	10·18	9·3	+0·88		+0·34
10	10·04	9·3	+0·74		+0·20
11	9·66	9·0	+0·66		+0·12
12	9·21	8·6	+0·61		+0·07
13	8·87	8·1	+0·77		+0·23
14	8·72	7·9	+0·82		+0·28
15	8·85	8·0	+0·85		+0·31
16	9·07	8·3	+0·77		+0·23
17	9·50	8·8	+0·70		+0·16
18	9·96	9·2	+0·76		+0·22
19	10·33	9·6	+0·73		+0·19
20	10·44	9·7	+0·74		+0·20
21	10·12	9·5	+0·62		+0·08
22	9·42	8·8	+0·62		+0·08
23	8·43	7·9	+0·53		−0·01

1859, March 29.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, C−R+ΔA_0.
0	7·43	6·9	+0·53	−0·60	−0·07
1	6·62	5·9	+0·72		+0·12
2	6·15	5·6	+0·55		−0·05
3	6·08	5·7	+0·38		−0·22
4	6·43	6·1	+0·33		−0·27
5	7·11	6·8	+0·31		−0·29
6	8·02	7·6	+0·42		−0·18
7	8·98	8·4	+0·58		−0·02
8	9·78	9·1	+0·68		+0·08
9	10·23	9·5	+0·73		+0·13
10	10·25	9·7	+0·55		−0·05
11	9·88	9·4	+0·48		−0·12
12	9·28	8·9	+0·38		−0·22
13	8·68	8·2	+0·48		−0·12
14	8·30	7·6	+0·70		+0·10
15	8·22	7·5	+0·72		+0·12
16	8·39	7·9	+0·49		−0·11
17	8·85	8·3	+0·55		−0·05
18	9·43	9·0	+0·43		−0·17
19	10·02	9·4	+0·62		+0·02
20	10·42	9·8	+0·62		+0·02
21	10·50	10·0	+0·50		−0·10
22	10·13	9·7	+0·43		−0·17
23	9·34	8·9	+0·44		−0·16

* There was a very violent change from mean level on this day, which accounts for the largeness of the differences.

70. The following is a comparison for twenty-nine days, commencing 1868, November 1, of the recorded heights as registered by the Manora self-registering tide-gauge, with the heights calculated from the tide-components determined from the analysis of the first year's observations (§ 67). In the calculation of the heights the mean level of the water as determined by the observations of the whole year was used. The difference between this mean level and the mean of the twenty-four hourly heights (corrected for all sensible lunar influence) for each day is also given. The effect of this is to greatly improve the differences (C−R). The following tide-components were omitted in the calculations:—the whole of the long-period tides, and the Helmholtz shallow-water quarter-diurnal tide MS; likewise the solar semi-diurnal elliptic (R and T) and the lunar diurnal elliptic tides (J and Q), the values of which have been obtained since the heights were computed. The computations are for *local* time.

1868, November 1.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.
0	8.80	8.8	0.00	+0.09	+0.09
1	6.86	6.8	+0.06		+0.15
2	4.85	4.8	+0.05		+0.14
3	3.22	3.3	−0.08		+0.01
4	2.25	2.4	−0.15		−0.06
5	2.21	2.4	−0.19		−0.10
6	3.21	3.6	−0.39		−0.30
7	5.00	5.4	−0.40		−0.31
8	7.10	7.2	−0.10		−0.01
9	9.00	9.0	0.00		+0.09
10	10.42	10.4	+0.02		+0.11
11	11.05	10.9	+0.15		+0.24
12	10.75	10.7	+0.05		+0.14
13	9.58	9.5	+0.08		+0.17
14	8.01	8.0	+0.01		+0.10
15	6.54	6.7	−0.16		−0.07
16	5.49	5.6	−0.11		−0.02
17	5.09	5.1	−0.01		+0.08
18	5.55	5.7	−0.15		−0.06
19	6.79	7.1	−0.31		−0.22
20	8.37	8.4	−0.03		+0.06
21	9.71	9.7	+0.01		+0.10
22	10.45	10.5	−0.05		+0.04
23	10.45	10.6	−0.15		−0.06

1868, November 2.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.
0	9.61	9.7	−0.09	+0.15	+0.06
1	7.97	7.9	+0.07		+0.22
2	5.90	5.8	+0.10		+0.25
3	3.96	4.0	−0.04		+0.11
4	2.60	2.7	−0.10		+0.05
5	2.05	2.3	−0.25		−0.10
6	2.40	2.7	−0.30		−0.15
7	3.77	4.2	−0.43		−0.28
8	5.74	6.0	−0.26		−0.11
9	7.84	8.0	−0.16		−0.01
10	9.61	9.8	−0.19		−0.04
11	10.71	10.8	−0.09		+0.06
12	11.06	11.0	+0.06		+0.21
13	10.45	10.4	+0.05		+0.20
14	9.17	9.1	+0.07		+0.22
15	7.60	7.7	−0.10		+0.05
16	6.28	6.4	−0.12		+0.03
17	5.50	5.6	−0.10		+0.05
18	5.38	5.5	−0.12		+0.03
19	6.06	6.4	−0.34		−0.19
20	7.41	7.6	−0.19		−0.04
21	8.88	9.1	−0.22		−0.07
22	9.93	10.1	−0.17		−0.02
23	10.34	10.5	−0.16		−0.01

1868, November 3.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.
0	10·01	10·3	−0·29	+0·25	−0·04
1	8·87	8·9	−0·03		+0·22
2	7·10	7·0	+0·10		+0·35
3	5·09	5·0	+0·09		+0·34
4	3·43	3·5	−0·07		+0·18
5	2·40	2·4	0·00		+0·25
6	2·22	2·4	−0·18		+0·07
7	2·92	3·3	−0·38		−0·13
8	4·45	4·9	−0·45		−0·20
9	6·47	6·9	−0·43		−0·18
10	8·43	8·8	−0·37		−0·12
11	9·92	10·2	−0·28		−0·03
12	10·75	10·9	−0·15		+0·10
13	10·82	10·9	−0·08		+0·17
14	10·05	10·0	+0·05		+0·30
15	8·71	8·6	+0·11		+0·36
16	7·28	7·4	−0·12		+0·13
17	6·22	6·4	−0·18		+0·07
18	5·69	5·8	−0·11		+0·14
19	5·78	6·2	−0·42		−0·17
20	6·56	7·1	−0·54		−0·29
21	7·81	8·5	−0·69		−0·44
22	9·05	9·5	−0·45		−0·20
23	9·83	10·2	−0·37		−0·12

1868, November 4.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.
0	9·94	10·4	−0·46	+0·25	−0·21
1	9·40	9·6	−0·20		+0·05
2	8·17	7·9	+0·27		+0·52
3	6·41	6·1	+0·31		+0·56
4	4·64	4·5	+0·14		+0·39
5	3·30	3·3	0·00		+0·25
6	2·62	2·7	−0·08		+0·17
7	2·68	2·8	−0·12		+0·13
8	3·55	3·8	−0·25		0·00
9	5·15	5·6	−0·45		−0·20
10	7·07	7·5	−0·43		−0·18
11	8·94	9·2	−0·26		−0·01
12	9·95	10·3	−0·35		−0·10
13	10·57	10·8	−0·23		+0·02
14	10·47	10·7	−0·23		+0·02
15	9·69	9·7	−0·01		+0·24
16	8·41	8·5	−0·09		+0·16
17	7·21	7·4	−0·19		+0·06
18	6·34	6·4	−0·06		+0·19
19	5·93	6·1	−0·17		+0·08
20	6·10	6·6	−0·50		−0·25
21	6·87	7·5	−0·63		−0·38
22	7·97	8·5	−0·53		−0·28
23	8·96	9·5	−0·54		−0·29

1868, November 5.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
0	9·42	9·9	−0·48	+0·33	−0·15
1	9·42	9·8	−0·38		−0·05
2	8·77	8·8	−0·03		+0·30
3	7·56	7·4	+0·16		+0·49
4	6·02	5·8	+0·22		+0·55
5	4·57	4·5	+0·07		+0·40
6	3·55	3·6	−0·05		+0·28
7	3·10	3·2	−0·10		+0·23
8	3·30	3·4	−0·10		+0·23
9	4·25	4·7	−0·45		−0·12
10	5·72	6·2	−0·48		−0·15
11	7·39	7·9	−0·51		−0·18
12	8·83	9·3	−0·47		−0·14
13	9·79	10·2	−0·41		−0·08
14	10·28	10·7	−0·42		−0·09
15	10·14	10·4	−0·26		+0·07
16	9·37	9·6	−0·23		+0·10
17	8·29	8·6	−0·31		+0·02
18	7·27	7·6	−0·33		0·00
19	6·49	6·7	−0·21		+0·12
20	6·11	6·5	−0·39		−0·06
21	6·21	6·9	−0·69		−0·36
22	6·88	7·7	−0·82		−0·49
23	7·79	8·6	−0·81		−0·48

1868, November 6.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
0	8·52	9·3	−0·78	+0·37	−0·41
1	8·87	9·5	−0·63		−0·26
2	8·81	9·4	−0·59		−0·22
3	8·25	8·5	−0·25		+0·12
4	7·26	7·4	−0·14		+0·23
5	6·02	6·1	−0·08		+0·29
6	4·85	5·1	−0·25		+0·12
7	4·10	4·3	−0·20		+0·17
8	3·76	3·9	−0·14		+0·23
9	3·98	4·2	−0·22		+0·15
10	4·75	5·1	−0·35		+0·02
11	6·06	6·5	−0·44		−0·07
12	7·49	7·9	−0·41		−0·04
13	8·71	9·1	−0·39		−0·02
14	9·58	10·0	−0·42		−0·05
15	10·04	10·4	−0·36		+0·01
16	9·93	10·3	−0·37		0·00
17	9·30	9·4	−0·10		+0·27
18	8·33	8·5	−0·17		+0·20
19	7·42	7·6	−0·18		+0·19
20	6·63	6·9	−0·27		+0·10
21	6·18	6·5	−0·32		+0·05
22	6·14	6·7	−0·56		−0·19
23	6·57	7·5	−0·93		−0·56

1868, November 7.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, C−R+ΔA_0.
	ft.	ft.	ft.	ft.	ft.
0	7·31	8·2	−0·89	+0·27	−0·62
1	7·93	8·7	−0·77		−0·50
2	8·28	8·9	−0·62		−0·35
3	8·33	8·9	−0·57		−0·30
4	8·03	8·3	−0·27		0·00
5	7·32	7·4	−0·08		+0·19
6	6·33	6·4	−0·07		+0·20
7	5·41	5·6	−0·19		+0·08
8	4·75	4·9	−0·15		+0·12
9	4·40	4·4	0·00		+0·27
10	4·47	4·6	−0·13		+0·14
11	5·10	5·3	−0·20		+0·07
12	6·15	6·3	−0·15		+0·12
13	7·38	7·8	−0·42		−0·15
14	8·55	8·9	−0·35		−0·08
15	9·39	9·8	−0·41		−0·14
16	9·91	10·2	−0·29		−0·02
17	9·88	10·1	−0·22		+0·05
18	9·32	9·4	−0·08		+0·19
19	8·44	8·4	+0·04		+0·31
20	7·44	7·5	−0·06		+0·21
21	6·61	6·7	−0·09		+0·18
22	5·93	6·2	−0·27		0·00
23	5·69	6·1	−0·41		−0·14

1868, November 8.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, C−R+ΔA_0.
	ft.	ft.	ft.	ft.	ft.
0	6·04	6·5	−0·46	+0·22	−0·24
1	6·66	7·2	−0·54		−0·32
2	7·31	7·8	−0·49		−0·27
3	7·82	8·3	−0·48		−0·26
4	8·13	8·5	−0·37		−0·15
5	8·13	8·4	−0·27		−0·05
6	7·69	7·9	−0·21		+0·01
7	6·93	6·9	+0·03		+0·25
8	6·09	6·1	−0·01		+0·21
9	5·38	5·3	+0·08		+0·30
10	4·88	4·8	+0·08		+0·30
11	4·79	4·7	+0·09		+0·31
12	5·23	5·2	+0·03		+0·25
13	6·20	6·3	−0·10		+0·12
14	7·32	7·5	−0·18		+0·04
15	8·44	8·6	−0·16		+0·06
16	9·39	9·5	−0·11		+0·11
17	10·00	10·2	−0·20		+0·02
18	10·06	10·2	−0·14		+0·08
19	9·49	9·4	+0·09		+0·31
20	8·50	8·4	+0·10		+0·32
21	7·35	7·4	−0·05		+0·17
22	6·25	6·3	−0·05		+0·17
23	5·40	5·4	0·00		+0·22

1868, November 9.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, C−R+ΔA_0.
0	5·04	5·2	−0·16	+0·23	+0·07
1	5·33	5·7	−0·37		−0·14
2	5·98	6·4	−0·42		−0·19
3	6·83	7·2	−0·37		−0·14
4	7·64	8·1	−0·46		−0·23
5	8·27	8·8	−0·53		−0·30
6	8·56	8·9	−0·34		−0·11
7	8·32	8·5	−0·18		+0·05
8	7·66	7·9	−0·24		−0·01
9	6·81	6·8	+0·01		+0·24
10	5·95	5·8	+0·15		+0·38
11	5·24	5·1	+0·14		+0·37
12	4·90	4·8	+0·10		+0·33
13	5·22	5·1	+0·12		+0·35
14	6·08	6·1	−0·02		+0·21
15	7·20	7·5	−0·30		−0·07
16	8·40	8·7	−0·30		−0·07
17	9·49	9·8	−0·31		−0·08
18	10·20	10·5	−0·30		−0·07
19	10·23	10·5	−0·27		−0·04
20	9·56	10·0	−0·44		−0·21
21	8·32	8·8	−0·48		−0·25
22	7·07	7·4	−0·33		−0·10
23	5·67	6·0	−0·33		−0·10

1868, November 10.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, C−R+ΔA_0.
0	4·59	4·9	−0·31	+0·40	+0·09
1	4·25	4·4	−0·15		+0·25
2	4·61	4·9	−0·29		+0·11
3	5·49	6·0	−0·51		−0·11
4	6·62	7·1	−0·48		−0·08
5	7·78	8·4	−0·62		−0·22
6	8·75	9·4	−0·65		−0·25
7	9·22	9·9	−0·68		−0·28
8	9·00	9·8	−0·80		−0·40
9	8·27	8·9	−0·63		−0·23
10	7·26	7·6	−0·34		+0·06
11	6·17	6·4	−0·23		+0·17
12	5·29	5·5	−0·21		+0·19
13	4·85	5·0	−0·15		+0·25
14	5·17	5·3	−0·13		+0·27
15	6·09	6·3	−0·21		+0·19
16	7·35	7·7	−0·35		+0·05
17	8·68	9·1	−0·42		−0·02
18	9·85	10·1	−0·25		+0·15
19	10·52	10·8	−0·28		+0·12
20	10·40	10·9	−0·50		−0·10
21	9·46	10·0	−0·54		−0·14
22	8·01	8·5	−0·49		−0·09
23	6·37	6·7	−0·33		+0·07

Hour.	Calculated height, C.	Recorded height, R.	Difference, C—R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	1868, November 11.				
	ft.	ft.	ft.	ft.	ft.
0	4·78	5·1	−0·32	+0·32	0·00
1	3·72	3·7	+0·02		+0·34
2	3·46	3·3	+0·16		+0·48
3	4·05	4·0	+0·05		+0·37
4	5·26	5·5	−0·24		+0·08
5	6·76	7·1	−0·34		−0·02
6	8·24	8·6	−0·36		−0·04
7	9·43	9·9	−0·47		−0·15
8	9·95	10·4	−0·45		−0·13
9	9·62	10·4	−0·78		−0·46
10	8·74	9·3	−0·56		−0·24
11	7·53	7·9	−0·37		−0·05
12	6·26	6·7	−0·44		−0·12
13	5·18	5·6	−0·42		−0·10
14	4·76	5·0	−0·24		+0·08
15	5·16	5·2	−0·04		+0·28
16	6·23	6·3	−0·07		+0·25
17	7·64	7·8	−0·16		+0·16
18	9·07	9·3	−0·23		+0·09
19	10·23	10·3	−0·07		+0·25
20	10·77	11·0	−0·23		+0·09
21	10·34	11·0	−0·66		−0·34
22	9·08	9·7	−0·62		−0·30
23	7·34	7·8	−0·46		−0·14

Hour.	Calculated height, C.	Recorded height, R.	Difference, C—R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	1868, November 12.				
	ft.	ft.	ft.	ft.	ft.
0	5·44	5·7	−0·26	+0·13	−0·13
1	3·79	3·9	−0·11		+0·02
2	2·82	2·7	+0·12		+0·25
3	2·82	2·5	+0·32		+0·45
4	3·79	3·4	+0·39		+0·52
5	5·39	5·2	+0·19		+0·32
6	7·16	7·2	−0·04		+0·09
7	8·90	8·9	0·00		+0·13
8	10·15	10·1	+0·05		+0·18
9	10·59	10·8	−0·21		−0·08
10	10·09	10·6	−0·51		−0·38
11	8·95	9·6	−0·65		−0·52
12	7·51	8·0	−0·49		−0·36
13	6·11	6·7	−0·59		−0·46
14	5·06	5·5	−0·44		−0·31
15	4·73	4·9	−0·17		−0·04
16	5·33	5·2	+0·13		+0·26
17	6·55	6·5	+0·05		+0·18
18	8·10	8·1	0·00		+0·13
19	9·72	9·5	+0·22		+0·35
20	10·57	10·4	+0·17		+0·30
21	10·81	10·8	+0·01		+0·14
22	10·06	10·4	−0·34		−0·21
23	8·48	8·8	−0·32		−0·19

Hour.	Calculated height, C.	Recorded height, R.	Difference, C—R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	1868, November 13.				
0	6·45	6·6	−0·15	−0·09	−0·24
1	4·46	4·3	+0·16		+0·07
2	2·87	2·8	+0·07		−0·02
3	2·11	1·8	+0·31		+0·22
4	2·50	1·9	+0·60		+0·51
5	3·87	3·4	+0·47		+0·38
6	5·79	5·6	+0·19		+0·10
7	7·83	7·7	+0·13		+0·04
8	9·63	9·2	+0·43		+0·34
9	10·80	10·6	+0·20		+0·11
10	11·00	11·1	−0·10		−0·19
11	10·26	10·6	−0·34		−0·43
12	8·90	9·2	−0·30		−0·39
13	7·33	7·6	−0·27		−0·36
14	5·94	6·2	−0·26		−0·35
15	4·98	5·1	−0·12		−0·21
16	4·77	4·8	−0·03		−0·12
17	5·69	5·5	+0·19		+0·10
18	7·08	7·0	+0·08		−0·01
19	8·60	8·6	0·00		−0·09
20	9·96	9·6	+0·36		+0·27
21	10·74	10·4	+0·34		+0·25
22	10·61	10·4	+0·21		+0·12
23	9·46	9·2	+0·26		+0·17

Hour.	Calculated height, C.	Recorded height, R.	Difference, C—R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	1868, November 14.				
0	7·59	7·2	+0·39	−0·26	+0·13
1	5·46	4·9	+0·56		+0·30
2	3·49	3·0	+0·49		+0·23
3	2·16	1·7	+0·46		+0·20
4	1·78	1·2	+0·58		+0·32
5	2·59	1·8	+0·79		+0·53
6	4·35	3·9	+0·45		+0·19
7	6·46	6·1	+0·36		+0·10
8	8·59	7·9	+0·69		+0·43
9	10·29	9·7	+0·59		+0·33
10	11·24	10·8	+0·44		+0·18
11	11·13	11·1	+0·03		−0·23
12	10·13	10·2	−0·07		−0·33
13	8·66	8·7	−0·04		−0·30
14	7·06	7·2	−0·14		−0·40
15	5·75	6·0	−0·25		−0·51
16	5·01	5·1	−0·09		−0·35
17	5·20	5·0	+0·20		−0·06
18	6·22	6·0	+0·22		−0·04
19	7·64	7·6	+0·04		−0·22
20	9·09	8·9	+0·19		−0·07
21	10·21	9·9	+0·31		+0·05
22	10·65	10·4	+0·25		−0·01
23	10·10	10·0	+0·10		−0·16

1868, November 15.					1868, November 16.					
Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.	Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.		ft.	ft.	ft.	ft.	ft.
0	8·66	8·5	+0·16	−0·16	0·00	0	9·35	9·2	+0·15	−0·18	−0·03
1	6·60	6·4	+0·20		+0·04	1	7·70	7·5	+0·20		+0·02
2	4·52	4·3	+0·22		+0·06	2	5·65	5·5	+0·15		−0·03
3	2·79	2·5	+0·29		+0·13	3	3·75	3·5	+0·25		+0·07
4	1·78	1·7	+0·08		−0·08	4	2·36	2·3	+0·06		−0·12
5	1·84	1·4	+0·44		+0·28	5	1·80	1·7	+0·10		−0·08
6	3·08	2·7	+0·38		+0·22	6	2·30	2·1	+0·20		+0·02
7	5·04	4·8	+0·24		+0·08	7	3·81	3·4	+0·41		+0·23
8	7·23	6·7	+0·53		+0·37	8	5·87	5·2	+0·67		+0·49
9	9·24	8·7	+0·54		+0·38	9	7·97	7·3	+0·67		+0·49
10	10·64	10·2	+0·44		+0·28	10	9·76	9·3	+0·46		+0·28
11	11·34	11·1	+0·24		+0·08	11	10·95	10·6	+0·35		+0·17
12	10·98	11·0	−0·02		−0·18	12	11·24	11·1	+0·14		−0·04
13	9·81	9·9	−0·09		−0·25	13	10·58	10·7	−0·12		−0·30
14	8·29	8·4	−0·11		−0·27	14	9·36	9·4	−0·04		−0·22
15	6·86	7·0	−0·14		−0·30	15	7·91	8·0	−0·09		−0·27
16	5·74	5·9	−0·16		−0·32	16	6·69	6·8	−0·11		−0·29
17	5·27	5·1	+0·17		+0·01	17	5·82	5·8	+0·02		−0·16
18	5·70	5·5	+0·20		+0·04	18	5·67	5·4	+0·27		+0·09
19	6·84	6·7	+0·14		−0·02	19	6·24	6·1	+0·14		−0·04
20	8·20	7·9	+0·30		+0·14	20	7·39	7·2	+0·19		+0·01
21	9·41	9·2	+0·21		+0·05	21	8·57	8·3	+0·27		+0·09
22	10·19	10·0	+0·19		+0·03	22	9·46	9·3	+0·16		−0·02
23	10·23	10·1	+0·13		−0·03	23	9·87	9·8	+0·07		−0·11

1868, November 17.						1868, November 18.					
0	9·57	9·6	−0·03	−0·10	−0·13	0	9·34	9·3	+0·04	−0·04	0·00
1	8·50	8·4	+0·10		0·00	1	8·81	8·7	+0·11		+0·07
2	6·77	6·7	+0·07		−0·03	2	7·62	7·4	+0·22		+0·18
3	4·89	4·8	+0·09		−0·01	3	5·99	5·8	+0·19		+0·15
4	3·33	3·4	−0·07		−0·17	4	4·42	4·5	−0·08		−0·12
5	2·35	2·5	−0·15		−0·25	5	3·26	3·5	−0·24		−0·28
6	2·24	2·2	+0·04		−0·06	6	2·67	3·0	−0·33		−0·37
7	3·01	3·0	+0·01		−0·09	7	2·88	3·1	−0·22		−0·26
8	4·67	4·4	+0·27		+0·17	8	3·92	4·1	−0·18		−0·22
9	6·69	6·4	+0·29		+0·19	9	5·57	5·7	−0·13		−0·17
10	8·56	8·2	+0·36		+0·26	10	7·37	7·3	+0·07		+0·03
11	10·00	9·7	+0·30		+0·20	11	8·91	8·9	+0·01		−0·03
12	10·84	10·7	+0·14		+0·04	12	9·99	10·0	−0·01		−0·05
13	10·84	10·9	−0·06		−0·16	13	10·50	10·5	0·00		−0·04
14	10·05	10·1	−0·05		−0·15	14	10·34	10·3	+0·04		0·00
15	8·89	8·8	+0·09		−0·01	15	9·55	9·4	+0·15		+0·11
16	7·66	7·8	−0·14		−0·24	16	8·46	8·4	+0·06		+0·02
17	6·66	6·6	+0·06		−0·04	17	7·47	7·4	+0·07		+0·03
18	6·11	5·8	+0·31		+0·21	18	6·74	6·5	+0·24		+0·20
19	6·16	5·8	+0·36		+0·26	19	6·38	6·1	+0·28		+0·24
20	6·82	6·6	+0·22		+0·12	20	6·54	6·3	+0·24		+0·20
21	7·80	7·6	+0·20		+0·10	21	7·18	7·1	+0·08		+0·04
22	8·71	8·6	+0·11		+0·01	22	7·99	7·8	+0·19		+0·15
23	9·26	9·2	+0·06		−0·04	23	8·60	8·5	+0·10		+0·06

1868, November 19.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.
0	8·85	8·9	−0·05	+0·09	+0·04
1	8·67	8·8	−0·13		−0·04
2	8·06	8·1	−0·04		+0·05
3	6·87	6·9	−0·03		+0·06
4	5·51	5·6	−0·09		0·00
5	4·32	4·6	−0·28		−0·19
6	3·54	4·1	−0·56		−0·47
7	3·31	3·8	−0·49		−0·40
8	3·72	4·1	−0·38		−0·29
9	4·81	5·0	−0·19		−0·10
10	6·36	6·6	−0·24		−0·15
11	7·84	8·0	−0·16		−0·07
12	9·07	9·0	+0·07		+0·16
13	9·83	9·9	−0·07		+0·02
14	10·12	10·3	−0·18		−0·09
15	9·81	9·9	−0·09		0·00
16	9·05	9·0	+0·05		+0·14
17	8·18	8·1	+0·08		+0·17
18	7·42	7·3	+0·12		+0·21
19	6·90	6·7	+0·20		+0·29
20	6·66	6·5	+0·16		+0·25
21	6·84	6·8	+0·04		+0·13
22	7·31	7·3	+0·01		+0·10
23	7·89	7·9	−0·01		+0·08

1868, November 20.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.
0	8·24	8·3	−0·06	+0·19	+0·13
1	8·31	8·5	−0·19		0·00
2	8·07	8·3	−0·23		−0·04
3	7·42	7·6	−0·18		+0·01
4	6·45	6·6	−0·15		+0·04
5	5·39	5·7	−0·31		−0·12
6	4·53	5·1	−0·57		0·38
7	4·08	4·7	−0·62		−0·43
8	4·05	4·5	−0·45		−0·26
9	4·59	4·9	−0·31		−0·12
10	5·63	5·9	−0·27		−0·08
11	6·89	7·1	−0·21		−0·02
12	8·13	8·2	−0·07		+0·12
13	9·02	9·1	−0·08		+0·11
14	9·58	9·7	−0·12		+0·07
15	9·71	9·9	−0·19		0·00
16	9·35	9·5	−0·15		+0·04
17	8·70	8·7	0·00		+0·19
18	8·00	7·9	+0·10		+0·29
19	7·40	7·2	+0·20		+0·39
20	6·93	6·8	+0·13		+0·32
21	6·73	6·6	+0·13		+0·32
22	6·83	6·9	−0·07		+0·12
23	7·23	7·3	−0·07		+0·12

1868, November 21.

0	7·57	7·7	−0·13	+0·13	0·00
1	7·75	7·8	−0·05		+0·08
2	7·78	7·9	−0·12		+0·01
3	7·60	7·7	−0·10		+0·03
4	7·08	7·2	−0·12		+0·01
5	6·35	6·6	−0·25		−0·12
6	5·61	5·9	−0·29		−0·16
7	5·00	5·5	−0·50		−0·37
8	4·72	5·1	−0·38		−0·25
9	4·80	5·1	−0·30		−0·17
10	5·29	5·6	−0·31		−0·18
11	6·23	6·3	−0·07		+0·06
12	7·32	7·3	+0·02		+0·15
13	8·23	8·3	−0·07		+0·06
14	8·92	9·0	−0·08		+0·05
15	9·35	9·5	−0·15		−0·02
16	9·44	9·6	−0·16		−0·03
17	9·07	9·2	−0·13		0·00
18	8·48	8·4	+0·08		+0·21
19	7·87	7·7	+0·17		+0·30
20	7·30	7·2	+0·10		+0·23
21	6·85	6·8	+0·05		+0·18
22	6·55	6·5	+0·05		+0·18
23	6·57	6·6	−0·03		+0·10

1868, November 22.

0	6·85	6·8	+0·05	+0·16	+0·21
1	7·14	7·0	+0·14		+0·30
2	7·36	7·3	+0·06		+0·22
3	7·45	7·5	−0·05		+0·11
4	7·38	7·5	−0·12		+0·04
5	7·09	7·3	−0·21		−0·05
6	6·56	6·9	−0·34		−0·18
7	5·98	6·4	−0·42		−0·26
8	5·57	6·0	−0·43		−0·27
9	5·36	5·5	−0·14		+0·02
10	5·40	5·6	−0·20		−0·04
11	5·82	6·0	−0·18		−0·02
12	6·62	6·7	−0·08		+0·08
13	7·55	7·6	−0·05		+0·11
14	8·29	8·4	−0·11		+0·05
15	8·88	9·1	−0·22		−0·06
16	9·25	9·6	−0·35		−0·19
17	9·26	9·6	−0·34		−0·18
18	8·92	9·2	−0·28		−0·12
19	8·28	8·4	−0·12		+0·04
20	7·62	7·7	−0·08		+0·08
21	7·00	7·0	0·00		+0·16
22	6·45	6·5	−0·05		+0·11
23	6·10	6·1	0·00		+0·16

1868, November 23.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C+R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.
0	6·06	6·0	+0·06	+0·19	+0·25
1	6·37	6·2	+0·17		+0·36
2	6·72	6·6	+0·12		+0·31
3	7·06	7·0	+0·06		+0·25
4	7·35	7·4	−0·05		+0·14
5	7·51	7·7	−0·19		0·00
6	7·38	7·8	−0·42		−0·23
7	7·01	7·4	−0·39		−0·20
8	6·53	6·9	−0·37		−0·18
9	6·11	6·4	−0·29		−0·10
10	5·82	6·1	−0·28		−0·09
11	5·79	5·9	−0·11		+0·08
12	6·13	6·2	−0·07		+0·12
13	6·85	6·8	+0·05		+0·24
14	7·67	7·7	−0·03		+0·16
15	8·41	8·5	−0·09		+0·10
16	8·98	9·1	−0·12		+0·07
17	9·29	9·5	−0·21		−0·02
18	9·26	9·6	−0·34		−0·15
19	8·80	9·1	−0·30		−0·11
20	8·05	8·3	−0·25		−0·06
21	7·23	7·7	−0·47		−0·28
22	6·48	6·9	−0·42		−0·23
23	5·89	6·1	−0·21		−0·02

1868, November 24.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	ft.	ft.	ft.	ft.	ft.
0	5·43	5·6	−0·17	+0·15	−0·02
1	5·49	5·5	−0·01		+0·14
2	5·95	5·8	+0·15		+0·30
3	6·44	6·3	+0·14		+0·29
4	7·03	7·0	+0·03		+0·18
5	7·59	7·7	−0·11		+0·04
6	7·94	8·2	−0·26		−0·11
7	7·92	8·4	−0·48		−0·33
8	7·56	8·1	−0·54		−0·39
9	7·01	7·4	−0·39		−0·24
10	6·50	6·8	−0·30		−0·15
11	6·12	6·3	−0·18		−0·03
12	5·99	6·1	−0·11		+0·04
13	6·29	6·1	+0·19		+0·34
14	7·00	6·8	+0·20		+0·35
15	7·86	7·7	+0·16		+0·31
16	8·62	8·5	+0·12		+0·27
17	9·16	9·1	+0·06		+0·21
18	9·46	9·5	−0·04		+0·11
19	9·30	9·5	−0·20		−0·05
20	8·64	8·9	−0·26		−0·11
21	7·67	8·0	−0·33		−0·18
22	6·64	7·0	−0·36		−0·21
23	5·66	6·0	−0·34		−0·19

1868, November 25.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
0	4·91	5·1	−0·19	+0·02	−0·17
1	4·62	4·7	−0·08		−0·06
2	4·88	4·6	+0·28		+0·30
3	5·59	5·2	+0·39		+0·41
4	6·46	6·1	+0·36		+0·38
5	7·32	7·1	+0·22		+0·24
6	8·13	8·0	+0·13		+0·15
7	8·60	8·6	0·00		+0·02
8	8·53	8·8	−0·27		−0·25
9	8·05	8·3	−0·25		−0·23
10	7·40	7·6	−0·20		−0·18
11	6·71	6·8	−0·09		−0·07
12	6·16	6·2	−0·04		−0·02
13	5·99	5·9	+0·09		+0·11
14	6·33	6·2	+0·13		+0·15
15	7·17	6·9	+0·27		+0·29
16	8·13	7·8	+0·33		+0·35
17	8·92	8·7	+0·22		+0·24
18	9·52	9·4	+0·12		+0·14
19	9·71	9·7	+0·01		+0·03
20	9·30	9·5	−0·20		−0·18
21	8·35	8·8	−0·45		−0·43
22	7·11	7·5	−0·39		−0·37
23	5·83	6·2	−0·37		−0·35

1868, November 26.

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
0	4·71	5·1	−0·39	+0·13	−0·26
1	3·99	4·2	−0·21		−0·08
2	3·90	3·9	0·00		+0·13
3	4·46	4·3	+0·16		+0·29
4	5·51	5·2	+0·31		+0·44
5	6·72	6·5	+0·22		+0·35
6	7·92	7·8	+0·12		+0·25
7	8·89	8·9	−0·01		+0·12
8	9·36	9·5	−0·14		−0·01
9	9·14	9·5	−0·36		−0·23
10	8·41	8·9	−0·49		−0·36
11	7·52	8·0	−0·48		−0·35
12	6·65	7·0	−0·35		−0·22
13	6·00	6·2	−0·20		−0·07
14	5·91	6·1	−0·19		−0·06
15	6·43	6·4	+0·03		+0·16
16	7·37	7·2	+0·17		+0·30
17	8·48	8·2	+0·28		+0·41
18	9·34	9·2	+0·14		+0·27
19	9·89	9·8	+0·09		+0·22
20	9·89	9·9	−0·01		+0·12
21	9·19	9·6	−0·41		−0·28
22	7·87	8·4	−0·53		−0·40
23	6·30	6·9	−0·60		−0·47

Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.	Hour.	Calculated height, C.	Recorded height, R.	Difference, C−R.	Excess of daily mean, ΔA_0.	Difference, $C-R+\Delta A_0$.
	1868, November 27.						1868, November 28.				
	ft.	ft.	ft.	ft.	ft.		ft.	ft.	ft.	ft.	ft.
0	4·87	5·4	−0·53	+0·15	−0·38	0	5·45	5·9	−0·45	+0·26	−0·19
1	3·70	4·2	−0·50		−0·35	1	3·88	4·4	−0·52		−0·26
2	3·09	3·4	−0·31		−0·16	2	2·75	3·2	−0·45		−0·19
3	3·30	3·4	−0·10		+0·05	3	2·40	2·7	−0·30		−0·04
4	4·28	4·2	+0·08		+0·23	4	3·01	3·1	−0·09		+0·17
5	5·73	5·5	+0·23		+0·38	5	4·42	4·6	−0·18		+0·08
6	7·31	7·1	+0·21		+0·36	6	6·24	6·2	+0·04		+0·30
7	8·69	8·5	+0·19		+0·34	7	8·04	7·9	+0·14		+0·40
8	9·70	9·7	0·00		+0·15	8	9·54	9·3	+0·24		+0·50
9	10·01	10·2	−0·19		−0·04	9	10·48	10·3	+0·18		+0·44
10	9·55	10·0	−0·45		−0·30	10	10·50	10·8	−0·30		−0·04
11	8·58	9·1	−0·52		−0·37	11	9·75	10·2	−0·45		−0·19
12	7·46	8·0	−0·54		−0·39	12	8·53	9·1	−0·57		−0·31
13	6·43	7·0	−0·57		−0·42	13	7·19	8·0	−0·81		−0·55
14	5·81	6·2	−0·39		−0·24	14	6·13	6·8	−0·67		−0·41
15	5·82	6·0	−0·18		−0·03	15	5·60	6·1	−0·50		−0·24
16	6·58	6·4	+0·18		+0·33	16	5·83	6·1	−0·27		−0·01
17	7·75	7·4	+0·35		+0·50	17	6·82	6·9	−0·08		+0·18
18	8·94	8·6	+0·34		+0·49	18	8·15	8·1	+0·05		+0·31
19	9·85	9·5	+0·35		+0·50	19	9·39	9·3	+0·09		+0·35
20	10·27	10·1	+0·17		+0·32	20	10·23	10·2	+0·03		+0·29
21	9·98	10·1	−0·12		+0·03	21	10·45	10·6	−0·15		+0·11
22	8·92	9·3	−0·38		−0·23	22	9·85	10·3	−0·45		−0·19
23	7·25	7·7	−0·45		−0·30	23	8·38	8·9	−0·52		−0·26

1868, November 29.

0	6·47	7·1	−0·63	+0·38	−0·25	12	9·71	10·3	−0·59		−0·21
1	4·52	5·1	−0·58		−0·20	13	8·26	9·1	−0·84		−0·46
2	2·94	3·6	−0·66		−0·28	14	6·88	7·8	−0·92		−0·54
3	2·00	2·8	−0·80		−0·42	15	5·84	6·6	−0·76		−0·38
4	2·01	2·5	−0·49		−0·11	16	5·48	6·0	−0·52		−0·14
5	3·07	3·3	−0·23		+0·15	17	5·93	6·2	−0·27		+0·11
6	4·87	5·1	−0·23		+0·15	18	7·14	7·4	−0·26		+0·12
7	6·94	7·1	−0·16		+0·22	19	8·58	8·7	−0·12		+0·26
8	8·85	8·8	+0·05		+0·43	20	9·79	9·8	−0·01		+0·37
9	10·33	10·3	+0·03		+0·41	21	10·49	10·4	+0·09		+0·47
10	11·03	11·2	−0·17		+0·21	22	10·43	10·7	−0·27		+0·11
11	10·77	11·2	−0·43		−0·05	23	9·48	9·8	−0·32		+0·06

Conclusion of Mr. Roberts's Statement.

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71. What may be regarded as the most interesting features of the work described in the preceding statement are the introduction of four new purely astronomical tides (the two evection-tides and the two variation-tides) and the new luni-solar Helmholtz compound shallow-water tide. Further investigation of the evection-tides is necessary and must lead to interesting results, on account of the great discrepancies between the results shown in § 61 above for the four years for which they have been calculated.

72. The fact noticed, that one of the variation-tides has the same period as the solar semidiurnal tide, would be of great importance for tidal theory were it not that its magnitude must be so small as to be scarcely sensible. According to the values of the perturbations in longitude and radius vector, due to variation shown in Hansen's Tables, the equilibrium value of the solar semidiurnal variation-tide would be only about $\frac{1}{30}$ of the equilibrium value of the $2(\gamma-2\sigma+\eta)$ variation-tide. The dynamical value of the latter tide, shown in § 61 above, is only about a quarter of a foot above and below the mean level. Hence it cannot be expected that the smaller component should sensibly influence the observed results obtained by the analysis which had been undertaken for the solar semidiurnal tide. The close agreement between the results, both for amplitude and for epoch, of the chief component variation-tide, $2(\gamma-2\sigma+\eta)$, for the four years, is so satisfactory that the evaluation is undoubtedly genuine in this case.

73. The same may be said also of the Helmholtz luni-solar tide. The effect of this tide is of great practical importance, especially in respect to navigation. It is well known that, generally in harbours, estuaries, and channels, the tide rises faster than it falls. The harmonic analysis of this phenomenon was given first, I believe, by Airy: see for example, his formula for Deptford in his article "Tides and Waves," Encyclopædia Metropolitana. Helmholtz's admirable explanation of the grave and acute notes heard accompanying two loud musical notes sounding simultaneously, referred to in § 24 of the Committee's First Report, contains a perfectly general statement of an extremely simple character, which, *mutatis mutandis*, is applicable to the tides in every case in which the range of rise and fall is sensible in comparison with the mean depth through any considerable area of sea or channel influencing them. The application of this theory, for example, to a tide of 10 feet whole range from mean level, considered as the resultant of two simultaneous tides of 5-feet range, suggests immediately the harmonic terms (such as those calculated by Airy for Deptford) which express the phenomenon of the rise being more rapid than the fall. The same theory applied to the spring-tides (which are the resultant of the lunar and solar semidiurnal tides when they agree in phase) and to the neap-tides (which are the resultant of the same components when they are opposite in phase), shows that the terms expressing deviation from the simple sum of the two chief harmonic terms must be greater than the sum of the deviations about the time of spring-tides, and less than the algebraic sum of the contrary deviations about the time of the neap-tides. Helmholtz's general statement again suggests instantly the harmonic terms proper to express the anticipated result. In this case it is the second of the two "shallow-water tides" indicated in § 24. The determination of this term from observation, promised at Norwich, 1868, as an early undertaking of the Committee, has now been accomplished, both for Liverpool and Ramsgate, by Mr. Roberts, in consequence of his having for some time been baffled by discrepancies in his investigation of the Liverpool tides showing an approximately quarter-diurnal period when all the components previously evaluated were properly put together to express the tides on the days selected for the comparison between theory and observation described above. The period of this new component is a quarter of the harmonic mean of the mean solar and mean lunar days. Its amplitude (that is, half the range from lowest to highest) is about $\frac{2}{5}$ of a foot at Liverpool and $\frac{1}{3}$ of a foot at Ramsgate. Both it and the previously found shallow-water components are greater in proportion to the chief tides at Ramsgate than at Liverpool; this no doubt is due to the great extent and shallowness of the

British Channel and German Sea, as compared with channels through which the ocean affects Liverpool.

74. The search for astronomical long-period tides has up to this time given only negative results. In each case a genuine annual tide seems to be indicated, but the negative results as to the lunar fortnightly (declinational) tide and monthly (elliptic) tide forbid us to regard either the semiannual or the annual as a truly astronomical tide. Both are probably due to meteorological causes. The cause which I have previously suggested (§ 10), that is, "water received into the sea by drainage and the melting of ice, and from the direct fall of rain into it," would tend to raise or lower the mean level almost simultaneously over the whole sea. There are two other meteorological causes which probably have very sensible effects,—difference in distribution of atmospheric pressure over the earth, and difference of temperature in different oceans. These three causes may be sufficient to explain the results of observation collected in the following Table :—

	Year.	Maximum of Annual Tide.	Range above and below mean level.	Maxima of Semiannual Tide.	Range above and below mean level.
			ft.		ft.
Ramsgate	1864	Sept. 21	0·127	Feb. 14, Aug. 15	0·075
Liverpool	1857–58, 1858–59, 1859–60, 1866–67	Nov. 19'	0·362	No agreement between the results for the different years.	
Fort Point	1858–59	April 29	0·212	Jan. 1, July 2	0·224
Kurrachee	1868–69	May 6	0·115	May 3, Nov. 2	0·198

75. In conclusion, it may be remarked that sailors find nearly all they want about the tides in British and Irish ports in the Admiralty Tide-tables, and the plan upon which they are constructed is available to give practical results of similar value for most of the Atlantic coasts. But this plan being adopted solely for lunar and solar semidiurnal tides, is absolutely unavailable to give any approach to good practical results for any ocean other than the Atlantic, as in all other oceans the diurnal tides are very considerable, and in many localities are greater than the semidiurnal tides.

76. There exist but few records of tidal observations on coasts where the diurnal tide is of this importance. Among those which do exist, however, are some made at Bombay and Kurrachee, which have been treated by Mr. Roberts and referred to in the foregoing Report.

77. Former observations at these two ports had previously been analyzed by Mr. Parkes, a member of this Committee, by a process described by him in a paper presented to the Royal Society, and published in the Philosophical Transactions for 1868, and which he has since amended in some of its details. Mr. Parkes has established formulæ based on astronomical data, which represent with considerable accuracy the movements of the diurnal tide; and Tables of the time and height of high and low water for the ports of Bombay and Kurrachee have been computed under his direction, and issued under the authority of the Secretary of State for India, for 1867 and each succeeding year. This constitutes undoubtedly the first successful comparison of theory and observation leading to sufficient tide-tables for any other than North-Atlantic ports. If observations were made at other points on the coast of India, and treated in a similar manner, further tables might be computed,

KURRACHEE T

DIAGRAM PREPARED BY MR. PARKES (§ 6

as observed ● as computed by Sir

The observed heights are plotted
and the computed heights
from the comparison, the oth

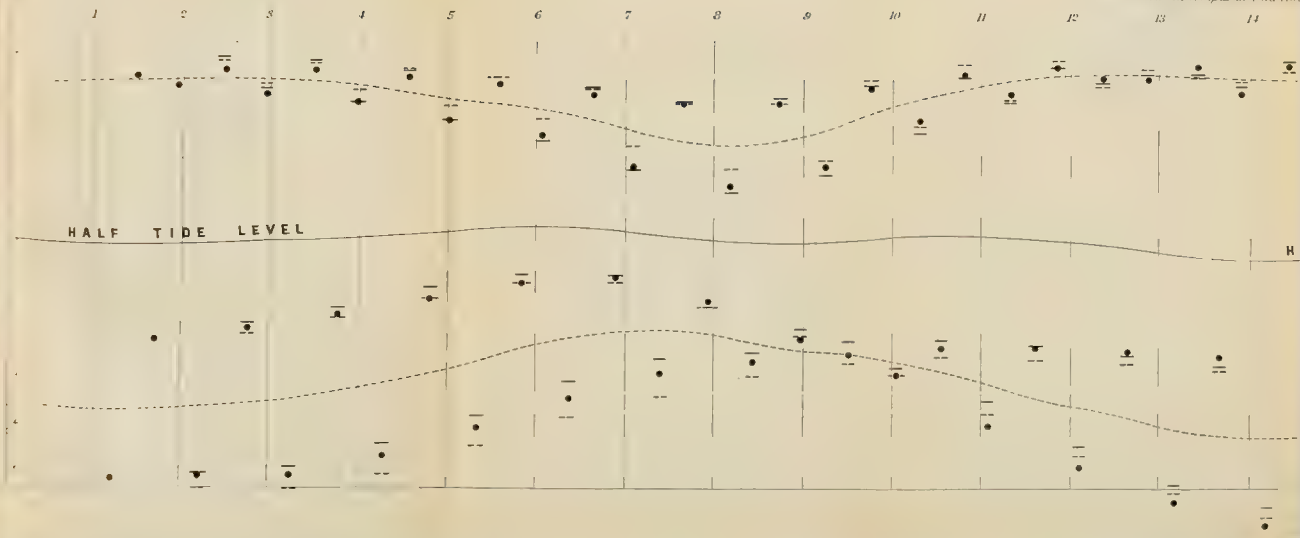


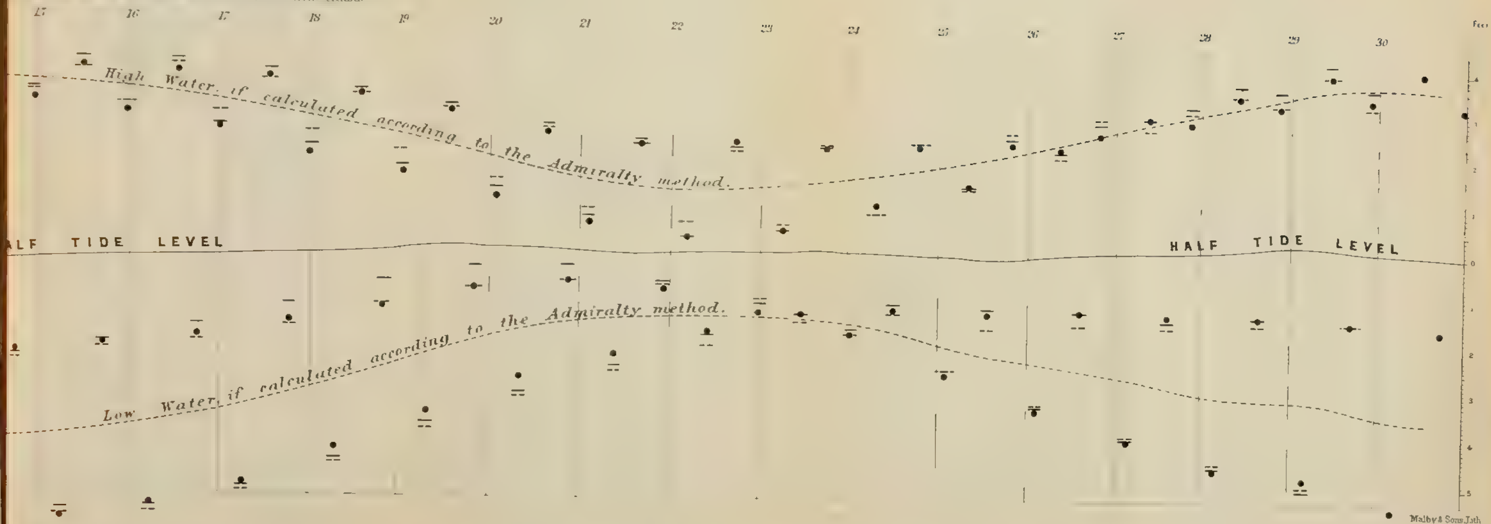
Plate 4*

TIDES. NOVEMBER 1868.

) TO SHOW THE COMPARATIVE HEIGHTS OF HIGH AND LOW WATER.

N.º Thomson's system — as computed by M.r Parkes' system - -

The half Tide level is deduced from them ... half Tide level so as to eliminate ... other than astronomical causes



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and those coasts placed generally in the same position with regard to knowledge of the tides as those of England. The same may be said of the ports of Australia, China, &c., as well as of western America.

78. But while admitting the practical sufficiency of Mr. Parkes's analysis for the purpose of establishing processes for the computation of tide-tables, the Committee believe the further application of the harmonic system to be very desirable, from its more searching character and the facility with which it exhibits the smaller variations of level independently of theory.

79. Whether it will, for practical purposes, supersede existing methods of prediction, will probably depend upon the relative amount of labour required for the calculations; but there is little doubt that it will at any rate facilitate the correction of existing formulæ.

80. For more strictly scientific purposes its superiority to any existing method of analysis is indisputable, and, considering the relation of tidal variations to many physical questions at present unsolved, its importance from this point of view is great.

81. It may fairly be expected that the Admiralty will cooperate in carrying on a work which, whether in its scientific or practical bearings, is of such fundamental importance for navigation.

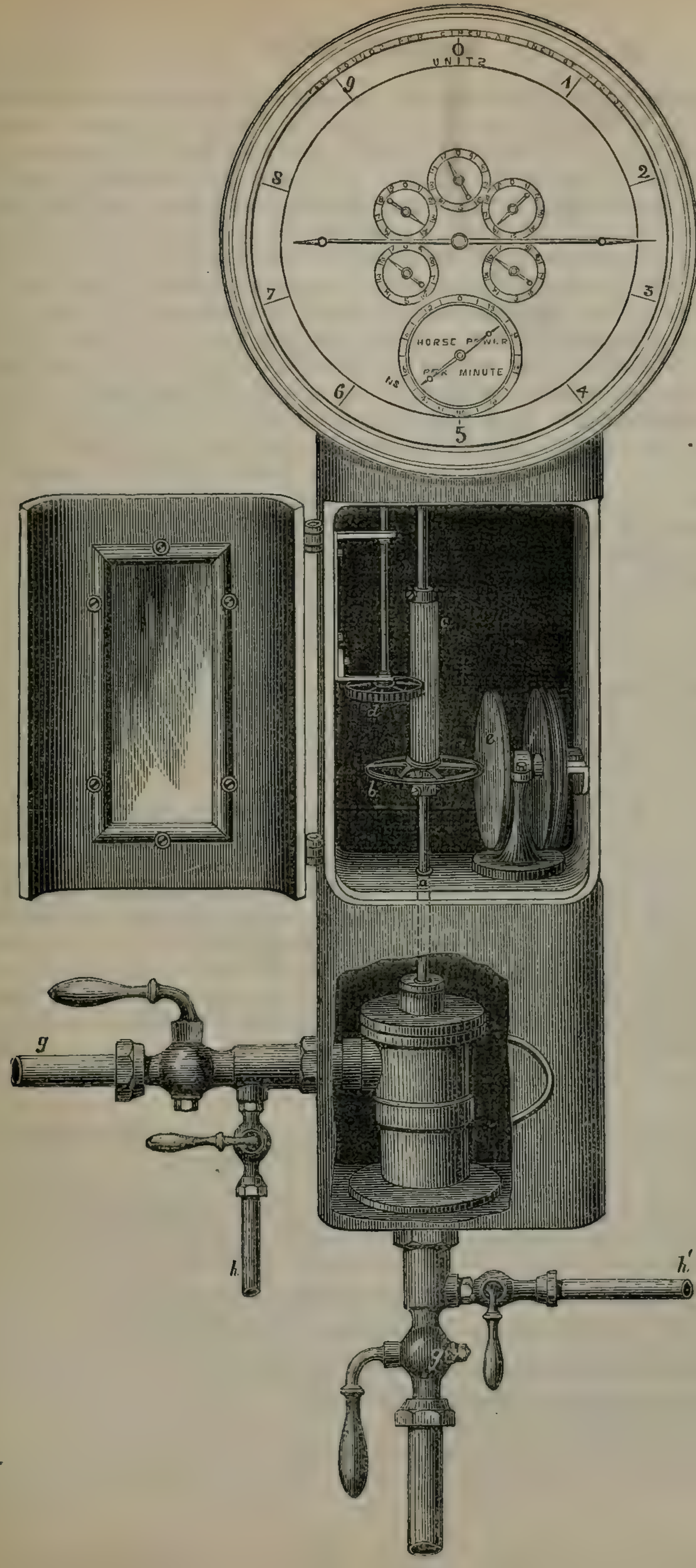
On a new Steam-power Meter. *By* Messrs. Ashton *and* Storey.

[A communication ordered to be printed *in extenso* in the Transactions.]

The extent to which the employment of steam-power in our varied industries, and as furnishing means of locomotion, has become a necessity, and the desirability of attaining the utmost economy in the consumption of fuel, render it a matter of the first importance to be able readily to ascertain the exact amount of power developed by steam machinery in a given time. Hitherto approximate estimates, founded upon the results of isolated tests and experiments, or calculations based upon the diagrams produced by ordinary indicators, have furnished the sole means for the ascertainment of the duty of (or, in other words, the power developed by) steam-engines in all cases where the said power has been subject to variations.

These indications have been taken at intervals of at least one day, and in most cases of a much longer period, and have simply been registrations of the amount of power developed during the one stroke or the two or three strokes performed by the engine during the time of indication, the great variations in the load upon or the speed of the engine, and in the pressure of the steam, occurring in the intervals between the indications being practically disregarded; and even when a correct diagram has been obtained, the power developed during the indication has and can only be ascertained with any degree of exactness by a tedious process of measurement and calculation. The patent power-meter and continuous indicator, on the contrary, not only measures the power developed during a single stroke of the engine with as great a degree of exactness as the best indicator hitherto in use, but also registers the result of the said measurement with as great a degree of exactness as it is measured, thus avoiding the errors arising in the operation of measuring and calculating the area of the ordinary diagram; and, what is of more consequence, this measure-

ment and registration are effected with reference to each and every stroke of the engine, and furnish a means whereby a correct judgment may be formed as to whether there has at any time been a want of due observance of economy in the use of fuel, or whereby the comparative merits of different kinds of fuel or of lubricants may be tested. In cases where power is supplied to tenants, this instrument furnishes the only means whereby the power so supplied may be accurately measured. And in the case of marine engines, in a rough sea it is the only instrument that can give any reliable information as to the power exerted by the steam-engines, inasmuch as it is frequently impossible to obtain consistent diagrams by the ordinary indicator during a whole voyage across the Atlantic. The steam-power meter and continuous indicator, as its name implies, shows at all times the measure of the power developed by the steam-engine to which it is applied, and registers the aggregate of that power during any required period of time. The instrument consists of a small double-acting indicator-cylinder $1\frac{1}{2}$ in. in diameter, each end of which is connected by means of a pipe with the corresponding end of the steam-engine cylinder. These connexions are made as short and direct as possible. The piston-rod of the indicator carries a long toothed pinion, *c*, which revolves loosely on the rod, but is held endwise between two screw-collars. This gears into a toothed wheel, *d*, which is connected with and drives the indices. At the lower end of the long pinion, and fixed to it, is a light wheel, *b*, called the integrating wheel, having a smooth rim with a rounded face. To the upper end of the piston-rod is attached a spiral spring, which offers a resistance to the free movement of the piston in its course from the middle to either end of the indicator-cylinder; on a short horizontal shaft is mounted a circular disk, *e*, whose face is constantly, but not forcibly, pressed against the rim of the integrating wheel. This is effected by means of a light flat spring bearing against the end of the shaft on which the disk-wheel is mounted. A small cog-wheel, *f*, is keyed on the disk-shaft, and is connected by a rack, or any other suitable means, to the cross-head or other convenient reciprocating part of the steam-engine, or a small pulley, *f*, may be keyed on the disk-shaft, round which is wound a cord, whose two ends are attached to the cross-head or other convenient reciprocating part of the steam-engine, being carried thence round loose pulleys above and below. By either of these means the reciprocating motion of the steam-engine is converted into a rotary motion of the disk acting in alternately opposite directions. When there is no pressure on the piston of the steam-engine, and accordingly none on the piston of the indicator, the integrating wheel is so adjusted that the point of contact of its rim with the disk shall be at the centre of the disk, that being the zero-point of the instrument. When the pressure of the steam is admitted, so as to act on the piston of the indicator, the integrating wheel traverses in consequence from the centre towards the circumference of the disk, the distance traversed being proportionate to the pressure of the steam on the piston. Suppose, now, the cross-head of the steam-engine, and with it the disk of the instrument, is moving, such motion will be communicated by the disk to the integrating wheel, and through it to the indices. The motion so given to the indices during this stroke of the steam-engine is proportionate to the pressure of the steam on the indicator-piston during that stroke. Let it now be supposed that the stroke is finished and a return movement is commenced, the disk will now rotate in the opposite direction; and if the steam acting upon the piston were pressing in the same direction as before, the inte-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grating wheel and indices would necessarily go backward. If, however, the steam, as is usual, acts on the opposite side of the piston when the piston's motion is reversed, the integrating wheel will be moved to the opposite side of the centre of the disk, so that the integrating wheel and indices will be moved in the same direction as before, and the quantity of motion through the receding stroke of the engine will again be proportionate to the pressure of the steam on the piston during that return stroke. Here, therefore, is provided a means of moving the indices during each stroke of the engine through a space proportionate to the sum of the moments of pressure exerted during that stroke, or, in other words, a means of indicating the amount of power developed during that stroke. The relative proportions adopted for the several working parts in the present instrument are such that each division on the dial represents one thousand foot-pounds of duty for each circular inch of the piston of the steam-engine. These proportions may be varied. Thus the parts of the indicator may be so arranged that the readings on the dial shall represent the number of horse-powers given out during any required period of time. By closing the tap connecting one end of the indicator-cylinder with the corresponding end of the steam-engine cylinder and opening the small drip-tap to admit air freely to the disconnected end of the indicator-cylinder, the indicator is rendered single-acting, and will show the manner of working and the amount of work done by one end of the steam-engine cylinder alone. By opening the closed taps and closing the open ones the indicator is reversed, and the manner of working and the amount of work done by the other end of the steam-engine cylinder ascertained. In the case of a non-condensing engine, the integrating wheel would not return to the centre of the rotating disk during the back or return stroke of the engine, by a distance proportionate to the back pressure opposing the motion of the steam-engine piston, the effect being that, during the return stroke, the integrating wheel and indices would be wound back by an amount of motion proportionate to the loss of power by back pressure. Also, if the valves of the engine are opened or closed too early or too late, the integrating wheel will be seen to move backward at the beginning or end of each stroke, thereby showing work undone by an amount of motion proportionate to the loss of power by such "cushioning" or too late admission of the steam or too late exhausting of it. The instrument can be so constructed that paper diagrams may be taken indicating the action of the steam in each end of the steam-engine cylinder, or in both ends conjointly.

Formula for showing the Relative Connexion of the Dimensions of the various parts of the Power-Meter.

Let w = the weight in lbs. required to distend or compress the spring one inch, d = diameter of indicator-cylinder in inches, D = diameter of integrating wheel in inches, l = number of teeth in the long pinion, m = number of teeth in wheel geared in long pinion, n = number of teeth in worm-wheel or first index-wheel, x = diameter of driving-pulley on disk-shaft; then d^2 = the area of the cylinder in circular inches, and $\frac{w}{d^2}$ = the pressure in pounds of steam per circular inch on the piston, to distend or compress the spring one inch.

One revolution of the disk with the integrating wheel one inch from the centre will drive the integrating wheel $\frac{2}{D}$ revolutions. Then

$$\frac{2}{D} \text{ of } \frac{l}{m} \text{ of } \frac{1}{n}$$

= the parts of one revolution of the index for one revolution of the disk—that is,

$$= \frac{2l}{Dmn}.$$

And because $\frac{w}{d^2} \times \frac{3\cdot1416x}{12}$ = foot-pounds represented by one revolution of the disk per one circular inch of the piston, $= \frac{3\cdot1416wx}{12d^2}$, therefore

$$\frac{3\cdot1416wx}{12d^2} \times \frac{Dmn}{2l} = \frac{3\cdot1416Dmnwx}{24ld^2}$$

= foot-pounds per one revolution of index. Or, assume one revolution of index = 10,000, then

$$\frac{3\cdot1416Dmnwx}{24ld^2} = 10{,}000 \text{ and } x = \frac{240{,}000ld^2}{3\cdot1416Dmnw} = \frac{76394\cdot194ld^2}{Dmnw}.$$

Therefore each unit on the dial of the power-meter represents 1000 foot-pounds per circular inch.

To find the Work done by an Engine in any given time.

When d = the diameter of the engine-cylinder in inches, n = the number of the meter-index at commencement of time, n = the number of the meter-index at the end of that time, therefore

$$1000\,(n_1-n)\,d = \text{foot-pounds}.$$

To find the work done in Horse effect.

Where m = number of minutes elapsed between the time of reading the meter, and 33,000 foot-pounds represents the duty of one horse per minute, then

$$\frac{1000(n_1-n)d^2}{33{,}000m} \cdot \frac{d^2(n_1-n)}{33m} = \text{load in horse-powers}.$$

To find the quantity of Coal consumed per Horse per hour.

Let H = horse effect of the engine, h = hours during consumption of the coal, w = the weight of coal in lbs., and $\frac{w}{h}$ = the number of lbs. of coal consumed per hour; also

$$\frac{1000(n_1-n)d^2}{33{,}000\times60h} = \text{H} = \frac{(n_1-n)d^2}{1980h}.$$

And $\dfrac{\frac{w}{h}}{\text{H}}$ = lbs. of coal consumed per horse per hour, therefore

$$\frac{w}{h} \times \frac{1}{\text{H}} = \frac{w}{h}\,\frac{1980h}{(n_1-n)d} \text{ or } \frac{1980w}{(n_1-n)d}$$

= consumption of coal per horse per hour.

Report on the Action of the Methyl and Allied Series. *By* Benjamin W. Richardson, *M.D., F.R.S.*

In my last Report to the Association I classified under five heads the various substances the action of which I had studied in a physiological point of view, viz. the Hydrides, Nitrites, Alcohols, Chlorides, and Iodides of Methyl, Ethyl, Butyl, and Amyl. In my present report I have retained the same order of classification of organic substances, so as to ensure a systematic and

steady progression, adding in due place what has been attempted in research with other organic bodies.

The matter I have to communicate in the present Report I shall place under three heads, which shall indicate the lines of inquiry I have aimed to carry out. I propose, *first*, to bring under review some of the work of the past, with such improvements upon it as have been since elicited by experience and experiment; *secondly*, to narrate the results of new researches with certain substances which have not before been tried by the physiologist, in respect to their action on the body; and, *thirdly*, to submit some conclusions deduced from experiments relative to the general physiological action of certain of the more active agents that have come before me for study.

PART I.—REVIEW.

Out of the list of compounds reported upon in previous years, I select for review nitrite of amyl, bichloride of methylene, methylic ether, and hydrate of chloral.

This selection is made because all the substances named have been found to have, in their application, a practical not less than a scientific value.

Nitrate of Amyl.—In 1863 I first reported to the Association on this chemical substance, the nitrite of amyl, treating then purely on its physiological properties, and venturing nothing in respect to its employment for the relief or cure of disease. In the following year, however, I made a further advance, and at the Meeting in Bath in 1864 I was able to state to the Association the true place of this nitrite as a physiological agent and as a remedy for disease. Ishowed then that its great virtue lay in its power of removing muscular spasm; for I had detected that beneath the action which it prominently calls forth, the excessive action of the heart and apparent excitement, there is another and more permanent condition produced, viz. a temporary paralysis of muscle and a suspension of all the outward manifestations of life which, in Batrachians, could be sustained without actually destroying life. These observations led me to point out the importance of employing the nitrite in order to control spasms, and especially to meet the spasmodic disease tetanus, commonly called locked jaw, over which I inferred it would have a direct controlling power.

In course of time this suggestion for the application of the nitrite for the relief of acute spasm came into practice, Dr. Brunton, of Edinburgh, leading the way by administering the remedy, with marked success, for the relief of what is called angina pectoris. Further experience has fully supported the introduction of the remedy, and in the past year there has been signal advance. In December last Dr. Anstie had recourse to the nitrite for the relief of angina, with the result that the sufferer passed (I use the author's own words) "from agony into a state of perfect repose." Dr. Farquhar has also reported that in an instance of terrible pain from spasm of the bowels, where the nitrite was administered, the patient expressed that he "was transformed from agony to heaven in a moment." Dr. Leischman, Dr. Hadden, and Dr. H. Thompson have borne similar testimony to the value of the agent. But the most striking example of the action of this potent remedy has been recorded in the 'Lancet,' in April of the present year, by a most experienced and learned practitioner, Mr. Foster, of Huntington. Mr. Foster had the opportunity of applying the nitrite in the disease tetanus, for which I recommended it in 1864, to a man who suffered from

this extreme malady, following upon the infliction of a wound. The spasms were so severe that the man is described as having "been rolled up like a rigid ball." Five drops of the nitrite were put on a pocket handkerchief and inhaled, with the immediate effect of lessening the spasms. On each return of the spasms the agent was assiduously administered, and by this means the spasms were held in check until the ninth day, when the patient had inhaled an ounce of the fluid. In this example there was complete recovery; and Mr. Foster reports that of seven similar cases of tetanus which he had previously treated in thirty-four years' practice all had died. He had met with no success until he had recourse to the nitrite of amyl.

You will excuse me of any charge of pride when I express the gratification I feel at these singular results, and you will allow me, I hope, to explain how obliged I am to this Association for the support it afforded me when I was first engaged on this subject of research. The satisfaction rests, first, on the practical facts I have named; but a second satisfaction is that the facts have shown the worth of scientific experimental inquiry, as preliminary to practical application, for the certain and systematic relief and cure of human suffering.

Nitrite of amyl was not introduced into use as a remedy against spasmodic diseases, including tetanus, by any mere accident. It was introduced on method of pure scientific investigation; its properties as a remedy were discerned and estimated, stated before it was applied for the cure of disease, and the results obtained were the simple expositions of the predictions made concerning its value.

In the course of the year I have studied the best means of keeping and administering this active nitrite. At the Meeting at Norwich I proposed that it should be kept in absolute alcohol, but I find that when it is exposed long in this way it undergoes change, by which its efficiency is to some extent impaired. I find also that diluted with alcohol the vapour of the nitrite does not pass off with sufficient rapidity to secure good action. At the same it is not well to use it undiluted, as that implies the measurement of it by drops or minims, a plan which is neither safe nor convenient. To meet these difficulties I have made for inhalation an etherial solution, or tincture, in which five grains of the nitrite of amyl are contained in one drachm of absolute ether.

I have seen no occasion to modify the view expressed at the Meeting at Bath, and again at the Meeting at Exeter last year, that the nitrite of amyl produces its effect by its paralyzing-action upon the nerves which govern the contraction of the blood-vessels; and I take it that this explanation of its action explains, by the reverse, the mode of action of those agents which it neutralizes, such as strychnia, and of the influence which excites the disease known as tetanus. It seems to me that these agencies either excite extreme action of the nerves which keep up the contraction, or paralyze the counter nervous supply which causes dilatation of vessels, and that the convulsive movements induced by such agents as strychnine are due to removal of blood by contraction of vessels in a manner analogous to that convulsion which follows free abstraction of blood.

Bichloride of Methylene.—Bichloride of methylene during the past year has grown much in favour, and in some of our large medical institutions has replaced chloroform altogether. I regret, nevertheless, to have to report that two deaths have been recorded as following upon its use. Both cases were peculiar. In one the subject was, in truth, so near to death at the time of administration that he was apprised by the surgeons and the able

administrator of the bichloride, Mr. Marshall, of the risk he incurred. In the other case the fatal event did not happen at the time of administration, but five minutes afterwards, and even after return of consciousness, a result entirely new, as far as I know, in the history of anæsthetic practice. I am unable altogether to account for this result; and the less able because the patient was never brought fairly under the influence of the narcotic, and received less of it than I have often inhaled in experiment.

On the whole, the rate of death, taking these two cases as *bonâ fide* examples of death, has been, relatively, very small, certainly not more than one in ten thousand administrations; and I am assured by those who administer the bichloride most frequently that continued practice only increases their confidence in it.

Dr. Junker, who has now administered bichloride of methylene over two hundred times for the most formidable operation in surgery (ovariotomy), expresses to me his belief that the agent is practically free of danger when it is obtained pure, and when ordinary care is taken in administering it; and other administrators have sent me reports equally favourable. For my own part I have simply allowed it to be adjudged upon by independent observers, retaining the opinion I first advanced in respect to it, that it is safer than chloroform, but not absolutely safe; that, like chloroform, it belongs to a dangerous family of chemical bodies, and that it is still the business of the experimentalist to search for an anæsthetic which shall be equally practical in application and, at the same, better in action.

Methylic ether.—In two previous Reports I have noticed methylic ether, and have explained that as a safe anæsthetic agent it has no superior. I have endeavoured consequently to utilize it during the past months, and have administered it twenty-seven times with success, in cases of surgical operation, in the human subject. Mr. Coles, Mr. Spencer Watson, Mr. Gregson, and others have also administered the anæsthetic with successful results. The object of these applications of methylic ether has been to supply a perfectly safe anæsthetic that would narcotize very rapidly, but with sufficient effect to allow the surgeon to perform short and painful operations. For this purpose the ether acted remarkably well; in seventeen instances sufficient insensibility was induced to enable the operation of tooth extraction to be performed without pain, and in all these instances recovery to perfect consciousness occurred within a minnte. There was also observed another fact, of which more anon, that while the persons who were subjected to the narcotic expressed and felt no suffering from the operation they underwent, they retained so much consciousness as to respond to requests made of them, and to converse during the whole period they were under the anæsthetic influence.

I have not pressed forward this method of annulling pain, because methylic ether cannot be rendered sufficiently stable for practical daily use. Being a gas, it is necessary either to condense it by pressure, or to saturate ethylic ether with it under the influence of cold. The first of these methods is distrusted as unpleasant to the operator, and the second is uncertain, because with elevation of temperature the light methylic vapour is diffused and lost, so that common ether alone remains.

The physiological action of methylic ether deserves nevertheless to be kept in mind: first, because of the power it possesses of destroying sensibility before it destroys the consciousness; and, secondly, because of its safety. So safe is it that an animal made to sleep with it into unconsciousness may remain breathing it for twelve minutes without dying; and if allowed, apparently, to die, may be recovered by artificial respiration so long as seven

minutes after the cessation of the respiration, *i. e.* after what appears to be actual death.

Chloral Hydrate.—It will be remembered by many that at Exeter last year the substance called hydrate of chloral was first discussed in this country. The news had recently arrived that the distinguished Liebreich, of Berlin, had discovered in this hydrate a powerful narcotic; and our associate, Mr. Daniel Hanbury, F.R.S., having fortunately brought a specimen of it to Exeter, the Physiological Department of the Biological Section deputed me to test the substance (with which Mr. Hanbury kindly supplied me) by direct experiment, and to report upon it during the sittings of the Section. Responding to the wishes of the Section, and ably aided by Dr. Kilburne King, of Hull, Dr. and Mr. Shapter, of Exeter, and other friends, I was enabled to draw up a report that has been published in the 'Transactions,' and which gave a fair and impartial estimate of the values of the new remedy. The notice of this Report, and of the discussion upon it in the general and scientific papers, created the intensest interest in the medical world. After my return to town, I had frequently from fifteen to twenty communications a day respecting chloral hydrate. At the request of members of the medical profession, I visited Birmingham, Bradford, York, Norwich, and other large towns in the kingdom, to demonstrate the action and application of the remedy, while in London I gave series of similar demonstrations. These efforts made the hydrate widely known in this country; but the inherent good qualities of the compound itself were its best and surest recommendation. Hence it settled in favour as it increased in popularity, and it has now become an instrument for the cure of disease scarcely second to any in the hands of the physician. If I were to say that a million of persons in sleepless pain had been made to rest quietly and painlessly under its benign influence, I should certainly not overrate the extent of its usefulness.

It is satisfactory to feel that the conclusions we arrived at last year have been, on the whole, thoroughly sustained by the practice that has ensued. I deduced, from the experiments which we performed, that the hydrate was not an anæsthetic in the common sense of the term, but that it sometimes induced a stage of hyperæsthesia; this has been confirmed by many who have followed in the same method of inquiry. I inferred that the hydrate could not be expected (as had been expected of it) to supersede the volatile anæsthetics as a means of relieving the pain of surgical operations; and this view has been fully confirmed by the results of several attempts to make it replace the ordinary anæsthetics. I inferred that the compound reduced the animal temperature in a signal degree; and this view, fully confirmed by the after experiments of Demarquay, has met with the general acceptance of observers. I was led to conjecture, from what I had seen of the influence of the hydrate in controlling strychnine tetanus, that it would probably not be a cure for acute tetanic spasm; and this view has been supported by the results of practice in many cases of tetanic disease. Lastly, I was led to maintain that the hydrate, if it took position, would do so as the rival only of the old and time-honoured organic compound, opium; and this view has been once more fully confirmed.

It may be accepted, I think, on the whole, that chloral hydrate, which to us thirteen months ago was an absolute novelty, is now a fixed and proved instrument for the cure of disease. It is readily and cheaply manufactured, and its administration is easy. That it will not be found to possess all the virtues which have been attributed to it in its early days is certain;

that, when calmly and impartially compared with opium and the derivatives of opium, it will rank as subordinate to its ancient and trusted rival is probable; and that it will be found less potent in relieving acute physical pain than in calming the senses and in producing deep, but not insensible sleep, is also probable. But whatever modification of thought may occur in regard to it, it is an established messenger between science and disease, and must henceforth find a place in the pharmacopœias of all civilized peoples.

PART II.—RESEARCH WITH NEW AGENTS.

Passing from the review of the past I come to the work of the present, adding it to the classified list of my last Report in the order in which its parts naturally come.

Hydrides.

Two additional hydrides have been studied, viz. the hydride of caproyl or hexyl, and the hydride of œnanthyl or heptyl.

Hydride of Caproyl or Hexyl.—Of this hydride, known commonly as light petroleum spirit, $C_6 H_{13} H$, a pure specimen is before us; it has a fluid density of ·669, a vapour-density of 43, taking hydrogen as unity, and a boiling-point of 154° F. It is insoluble in water. It is not an unpleasant vapour to inhale, and it produces sleep when it is inhaled very much as chloroform does. The second degree or stage of narcotism, stage of excitement, is prolonged, and vomiting is not uncommon during this stage; when the third degree of narcotism is reached there is perfect insensibility. The fourth degree is attended with great muscular prostration, but recovery from the narcotism begins in from three to four minutes, and is usually rapid, no injurious effects being left behind. The temperature of animals (pigeons and rabbits) during the full influence of this anæsthetic falls from two and a half to three degrees Fahrenheit. When a warm-blooded animal, narcotized with the hydride of hexyl, is allowed to sleep to death in the vapour, the death, as from chloroform, is almost imperceptible, it is so gentle; the respiration ceases first, but the heart soon follows in cessation of action. After death the lungs are found to be slightly blanched, but the heart contains blood on both sides. The vapour in no way modifies the coagulation of blood, but the colour of the venous blood is rendered darker than is natural, and the arterial blood is also darkened. The corpuscles are not visibly changed.

I should consider the hydride of caproyl in the light of a narcotic which acts by reducing the respiratory process of change of blood rather than by direct influence of its own on the nervous centres. In the absence of chloroform it might be used as a substitute for it; and had it been tried pure in the early days of anæsthetic research, it would possibly have obtained position over ether. We need not, however, consider it at the present time any further, as we have better agents at our command.

Hydride of Œnanthyl or Heptyl.—This hydride, which may be obtained in a pure form by careful fractional distillation from some petroleum oils, is composed of $C_7 H_{15} H$. It has a specific gravity of ·709 at 60° F., a vapour-density of 50°, and a boiling-point of 201° F. It has a rather agreeable odour, and is easily inhaled. Administered by inhalation, it produces a stupor with some insensibility, much muscular tremor, and a reduction of temperature, which in birds may be brought down to not less than five degrees. It also reduces the action of the heart, while it quickens the respiration. It darkens arterial blood, but does not interfere with the process of coagulation of blood.

It is distinctly negative in its narcotic effects, and, from what we now know of it, is not a practical narcotic.

In order to render more complete the research with the hydrides, they were administered by subcutaneous injection in several experiments. Introduced into the body in this manner, they were found to be practically negative in their action, a dose, amply sufficient to produce stupor and death by inhalation, being inactive when the agent was carried into the organism by the hypodermic method. Moreover the local effects were so exceedingly slight, that they are unworthy of mention. The insolubility of the fluids in the blood and their negative chemical action can only account for these results.

Alcohol Series.

In previous Reports I have dealt with the physiological action of the alcohol series from methylic alcohol up to amylic alcohol. In the present Report I have dealt with certain alcohols in which a new element is introduced, viz. sodium alcohol, or sodium ethylate, potassium alcohol, or potassium ethylate, and sulphur alcohol, mercaptan. Regarding these substances, the sodium and potassium alcohols, are instances in which the metals sodium or potassium replace one atom of the hydrogen of the radical of the alcohol, while, in respect to the sulphur alcohol, the sulphur replaces the oxygen of the alcohol.

Alcohol.	Sodium alcohol.	Potassium alcohol.	Sulphur alcohol.
$\left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}O$	$\left.\begin{matrix}C_2H_5\\Na\end{matrix}\right\}O$	$\left.\begin{matrix}C_2H_5\\K\end{matrix}\right\}O$	$\left.\begin{matrix}C_2H_5\\H\end{matrix}\right\}S.$

The object of this research was to ascertain what would be the effect of introducing a new element, by substitution, into a substance, alcohol, the physiological action of which was understood.

Sodium Alcohol, or Ethylate Sodium.—This ethylate is prepared by treating absolute alcohol with pure metallic sodium. So soon as the sodium comes in contact with the alcohol there is free escape of hydrogen, and the addition of sodium has to be continued until action ceases. I find it good to increase the temperature gradually as the action declines. At last there is obtained a thick, nearly white product, which is a saturated solution of sodium alcohol. From the solution ethylate of sodium crystallizes out in beautiful crystals.

The composition of sodium ethylate is $\left.\begin{matrix}C_2H_5\\Na\end{matrix}\right\}O$. When it is brought into contact with water it is decomposed, the sodium becoming oxidized by the oxygen of the water to form sodium hydrate, and the hydrogen of the water going to reconstitute the common or ethylic alcohol.

The change of ethylic alcohol into sodium alcohol transforms it from an irritant to a caustic. Laid on dry parts of the body the sodium ethylate is comparatively inert, creating no more change than the redness and tingling caused by common alcohol; but so soon as the part to which the substance is applied gives up a little water, the transformation I have described above occurs; caustic soda is produced in contact with the skin in proportion as water is eliminated by the skin, and there proceeds a gradual destruction of tissue, which may be so moderated as hardly to be perceptible, or may be so intensified as to act almost like a cutting instrument.

Potassium Alcohol, or Potassium Ethylate.—Potassium ethylate is made in a similar manner as sodium ethylate, viz. by bringing pure potassium into contact with absolute alcohol. The action of the potassium is much

more energetic than sodium. I prefer to immerse the potassium under the alcohol in a small glass bell, from which there is a tube to allow of the escape of the liberated hydrogen. When saturation is complete, a thick and almost colourless fluid is formed, from which the ethylate may be obtained in solid crystalline state. Exposed to water the potassium ethylate is transformed, as is the sodium ethylate, into ethylic alcohol and hydrate of potassium. The composition of the potassium alcohol is $\left.\begin{matrix} C_2H_5 \\ K \end{matrix}\right\} O$.

The action of this compound on animal tissues, living and dead, is the same as that of the sodium compound, but is more energetic.

Practical Uses of Sodium and Potassium Alcohols.—I do not as yet see the means of applying readily these two active alcohols for internal administration, but I can predict for them a very extensive application for external purposes. They are most potent caustics. In some cases they may be employed to destroy, rapidly, such morbid growths as are not favourable for excision by the knife. In many cases of cancer they will prove invaluable, and will, I believe, exert a direct local curative influence. Injected subcutaneously into morbid growths, they would so quickly destroy them that the action might have to be conducted while the body was under the influence of an anæsthetic.

In being applied direct to the sensitive unbroken skin, I find that their destructive action is less painful than would be expected. I have made with both compounds a superficial eschar on my arm, with no more pain than a slight tingling warmth. What is more, when pain is felt, it may be checked quickly by dropping upon the part a little chloroform, which decomposes the alcohol, converting it into a chloride salt, and an ether of which I have yet to speak.

Again, I find that these alcohols dissolve some of the vegetable alkaloids. Thus opium may be dissolved in them, and a solution of opium in caustic alcohol is made directly by mere addition of the narcotic to the caustic spirit. Practical men will see the advantages of combinations of these alcohols with narcotics. The practice opens the way to one of the greatest needs in medicine, a sure, rapid, and painless caustic.

The caustic alcohols may be used in combination with local anæsthesia from cold. A part rendered quite dead to pain, by freezing with ether spray, could be directly destroyed by the subcutaneous injection of caustic alcohol, a practice very important in the treatment of poisoned wounds, such as the wound from the bite of a snake or a rabid dog. It is by no means improbable that some cystic tumours may be cured by the simple subcutaneous injection of a little of these fluids, after destruction of sensibility by cold.

Potassium and sodium alcohol, added to the volatile hydride of amyl, dissolve in the hydride and produce a caustic solution. When this solution is applied to the skin, the evaporation of the hydride takes place, and a layer of the caustic substance is left behind. This application would prove very useful to the surgeon in many cases of disease.

The action of the ethylates on the blood is extremely rapid and marked. The red corpuscles are brought into solution, and there forms (quickly in some cases) an almost instant crystallization of blood; the crystals are acicular, and spread out in arborescent filaments. The arborescent appearance is identical with the crystallization of the ethylates themselves in a thick fluid, but the smaller radiant crystals are due, I believe, to the crystallization of the crystalloidal matter of the blood-cells. They are singularly like the

crystalline forms which have been described, since the time of Dr. Richard Mead, as occurring in the blood after infection by the poison of the viper. One other peculiarity in the action of the ethylates on blood is worthy of notice: while they seem to attack and dissolve the red corpuscles vigorously, they act with comparative slowness on the white corpuscles, so that we may often see a white corpuscle floating uninjured in a sea of red colouring fluid previous to crystallization, and even adhering to the crystalline points after crystallization.

The ethylates possess also powerful antiseptic properties, so that even nervous matter, which of all animal substance is most prone to decomposition, can be long kept in good preservation in the presence of them. I have by me, in bottles, specimens of the brain of sheep which illustrate this point. Specimen 1 is inclosed in common air, and is a decomposed fluid mass. Specimen 2 is inclosed in the same volume of air, with twenty grains of absolute alcohol: this specimen is decomposed. Specimen 3 is inclosed in the same volume of air, with twenty grains of the ethylate of sodium; it remains firm, of perfectly natural colour, and free of decomposition. The specimens have been now under observation for fifteen weeks.

Sulphur Alcohol, Mercaptan.—The sulph-hydrate of ethyl, sulphur alcohol, or, as it was originally called by its discoverer, Zeise, "mercaptan," is made by saturating an alcoholic solution of potassa with sulphuretted hydrogen, and then treating the solution with iodide of ethyl. In its pure state it is a whitish fluid, and of so offensive and penetrating an odour that it cannot, until it is diluted with common alcohol or ether, in both of which it is freely soluble, be comfortably employed in experiment. It is insoluble in water. Its specific gravity is ·832 at 70° F.; its boiling-point is 135° F., and its vapour-density, by side of hydrogen, is 31. It is nearly insoluble in water, but imparts to water its peculiar odour, and can be distributed freely through it if combined with alcohol.

In order to experiment with mercaptan, it is necessary to dilute it either with absolute ether or alcohol; a solution containing one per cent. is sufficiently active.

When blood is acted upon by mercaptan no change of colour is produced, neither is the action of peroxide hydrogen on blood influenced by its presence. The corpuscles are made shrunken by it, but are not destroyed, their form changing into ovoid, with the same production of truncated corpuscles which I described in my last Report as belonging to the action of ordinary alcohol.

When mercaptan is cautiously inhaled the physiological effects are most peculiar. I found, by a direct experiment made on myself, that the vapour is nowise irritating, but that systemic effects are very speedily pronounced. There is desire for sleep, and a strange unhappy dreamy sensation, as if from some actual or impending trouble. This is succeeded by an easy but extreme sensation of muscular fatigue; the limbs feel too heavy to be lifted, and rest is absolutely demanded. There is at the same time no anæsthesia and no sign of intoxication. The pulse is rendered feeble and slow, and remains in that condition for one or two hours. In time all the effects pass off, and no unpleasant symptom remains. Active motion in the air very quickly gives entire liberation from the effects of the agent.

The same effects are produced on the inferior animals. Frogs exposed to the vapour pass slowly into sleep, and if the inhalation be sustained, there is complete arrest of the acts of respiration and circulation, followed by arrest of movements of the limbs. In this condition the animals lie to all

intents dead, except that there is no contraction of the pupil; indeed the pupil is dilated, and the lens stands out perfectly clear and bright. They may be left in this apparently lifeless state for half an hour in the vapour without danger. Taken out, gently washed with water, and left in the open air at 60° to 65° F., they invariably show signs of muscular movement in an hour and a half or two hours; then they recommence to breathe, next the heart begins to beat, and in a short time they recover perfectly, precisely as if they were awakening from the torpor of cold.

Respecting this recovery there is observed a phenomenon which to me is entirely new. It is the case with all narcotic and paralyzing agents which I have tested, that they produce paralysis of the voluntary muscles before they cause paralysis of the muscles of respiration and the heart. Also in recovery from the narcotic state, the heart first lights up, then the respiration, and finally the muscles of voluntary power. But under mercaptan the reverse obtains, the voluntary muscles lose their irritability last and regain it first during recovery.

The paralyzing action of mercaptan on muscle suggested to me that it might be useful for the arrest of tetanic convulsion, but experiment gave a negative to this hypothesis. It is true that the action of strychnine can be modified by this agent, but nothing more can be done with it. The passive muscles, so soon as the respiration is paralyzed, pass into slow but firm cadaveric rigidity.

A point of great physiological interest attaches to the mode of elimination of sulphur alcohol from the living body. Insoluble in the blood, and at the same time volatile, it makes its way out of the economy mainly by respiration, conveying an odour which is identical with the odour of the breath in some forms of disease. It would be out of place for me to enter on the question of disease here at any length; but I must not refrain from suggesting to physicians that a new field of inquiry is open to them in investigating the question of the presence of sulphur compounds in the air expired by their patients. In disease the breaking up of the albuminoid textures is attended within the body by the formation of volatile sulphuretted organic compounds, and the circumstance of the detection of such compounds in expired air would, I think, prove a most useful study in the art of diagnosis. When we know how minute a proportion of sulphur alcohol will produce muscular depression and feebleness of the heart, we may fairly infer that the formation of sulphur compounds spontaneously *within* the body would account for many examples of excessive temporary prostration, for the cause of which we have as yet no satisfactory explanation.

The mode of action of sulphur alcohol appeared to me at first to be through direct interference with the oxidation of the blood. I believed it to be an agent which arrested the natural oxidation of the blood by contact, but I am now not decided on this point. The substance inflicts no important structural lesion on the blood or tissues so long as it can find exit from the body; but while it is present it sustains a peculiar action on the nervous organism, not leading, I think, to any modification of structure, but causing exhaustion or arrest of motor power and disordered cerebral manifestation.

I have spoken thus far only of the action of sulphur alcohol, but it has some practical value to which, in a line or two, I may refer. It is an antiseptic, but gives to the matter it preserves an objectionable odour, which is not altogether removed even by boiling water. It is an excellent preparation for making a sulphur-bath, and would prove, in cases where sulphur has to

be applied externally, a useful agent. If it be true that sulphur compounds are of service in the treatment of so-called zymotic diseases, this alcohol would be a ready remedy of the sulphur class.

New Research on the Ethyls.

From studying the action of sulphur alcohol, I thought it well to pass to the ether of the sulphur series, $\left.\begin{matrix} C_2 H_5 \\ C_2 H_5 \end{matrix}\right\} S$, sulphide of ethyl. This ether, which is the analogue of the common rectified ether of the oxygen series, is made by bringing sulphide of potassium into contact with chloride of ethyl. It is a whitish fluid of offensive odour. It boils at 194° F., and its vapour-density is 45. It is slightly soluble in water and in blood. Although disagreeable to breathe, it can be administered by inhalation like common ether, and it produces, in like manner, sleep; the action of it is slow in comparison with that of common ether, but the recovery from its effects is quick, much quicker than from mercaptan. A very minute dose is sufficient to narcotize; a quarter of a grain, diffused in fifty cubic inches of air at 60°, will narcotize frogs; and when these animals are thus rendered insensible they may be left in the narcotic vapour, with all evidences of life lost, for periods of twenty-five minutes to half an hour without risk. Placed in the open air, the animals begin to move again in one or two minutes, the muscles of the limbs regaining their irritability sooner than the heart and the muscles of respiration.

On rabbits, guineapigs, and pigeons sulphide of ethyl acts directly as a narcotic and anæsthetic. In pigeons it reduces the animal temperature four degrees at the fourth stage of narcotism, and the muscular prostration is intense; at the same time the danger of death, if due care be taken, is slight.

If four-fifths of a grain of the sulphide of ethyl be ejected subcutaneously into the rabbit, the odour of the substance is detectable within a few seconds in the expired breath, but no general effect is produced. Narcotism can nevertheless be caused by the subcutaneous method.

A number of experiments were carried out in order to determine whether the sulphide of ethyl could be successfully employed to counteract the action of strychnia, but the results were not of a character to lead to the idea that the sulphide is an antidote for strychnia.

The vapour of sulphide of ethyl inhaled from a solution of one part in twenty of alcohol is less diagreeable than might be assumed. It causes, if the inhalation be cautiously carried out, but little irritation, and the influence of it as a narcotic is very much like that of sulphuric ether. It induces much less muscular exhaustion than mercaptan, and it gives to the breath an odour which lasts some hours after the inhalation has ceased.

Bromide of Ethyl.

Bromide of ethyl, or hydrobromic ether, $C_2 H_5 B_2$, was introduced as an anæsthetic by the late Mr. Nunneley of Leeds in 1849. The ether is made by distilling four parts of powdered potassium bromide with five parts of a mixture containing an alcoholic solution of strong sulphuric acid, one part of the acid in 96 of alcohol. The ether is a rather pleasant fluid to inhale. It boils at 104° F.; it has a specific gravity of 1·400; its vapour-density is 54.

Mr. Nunneley up to the time of his death held this fluid to be the best and safest of anæsthetics; and in an interview I had with him shortly before

his death, he begged me to study it and notice it in this Report.

I therefore undertook the task, and with a very excellent specimen of the ether prepared by Messrs. Robbins, chemists, I subjected it to a fair test by the side of other anæsthetic vapours, and found it to be a rapidly acting and safe agent. In doses of fifteen minims, diffused in 300 cubic inches of atmospheric air, at a temperature of 60° to 66° F., it induced profound narcotism in one minute and thirty seconds, both in pigeons and rabbits; and in the human subject one fluid drachm administered by Junker's inhaler was effective in entirely removing consciousness of pain after two minutes' inhalation. The effect of the ether is singular in that, under its use, very little muscular or nervous excitement precedes the narcotism; indeed there may be said to be no second degree of anæsthesia from the bromide, but a direct transition from the first to the third degree. The third degree is, moreover, free of spasmodic effort, and quickly passes, if the inhalation be continued, into the fourth degree of general muscular prostration. The temperature of the body is reduced in the fourth stage full 3° F. Recovery from the deepest narcotism produced by it is perfect in from four to five minutes, and in no experiment did I observe any symptom of danger.

I am thus able to state that Mr. Nunneley's opinion respecting hydrobromic ether was sound; and could the ether be obtained as readily as chloroform, and were it as stable a body, I should say that it would be a real improvement on chloroform. Its physical qualities, its low boiling-point especially, are good recommendations; and the facts that it causes no convulsion, and that recovery from its influence is very rapid, are equally in its favour. The objections to it, irrespective of cost of its production, which is great, are that its vapour provokes during its inhalation a local dryness and irritation of throat, easily bearable but not pleasant, and that on being kept for a time and exposed to air it undergoes change, so that its vapour becomes actually irritating to the mucous membrane. These faults, minor though they be, would, I think, prevent hydrobromic ether from coming into general use as an anæsthetic; its good qualities deserve nevertheless to be remembered, and the scientific world is much indebted to our late Associate for the labour he introduced into his research and the results he obtained.

Triethylic and Trimethylic Ethers.

When chloroform is made to act on sodium or potassium ethylate, or on sodium or potassium methylate, a chloride of the metals, whichever be used, is formed and an ether. If an ethylate be acted upon an ethyl ether is obtained; if a methylate be acted upon a methyl ether. The first of these ethers is supposed to be homologous with an ether of a triatomic alcohol called triethylic, $C_7 H_{16} O_3$, and I have therefore called it triethylic ether; the second is homologous with trimethylic ether, $C_4 H_{10} O_3$: specimens of both these ethers are on the table.

Triethylic ether is a heavy aromatic fluid, boiling at 174° F., and having a vapour-density of 71. It passes into vapour very slowly, unless the temperature of the air be considerably raised, and hence at ordinary temperatures the action of the ether is very faint when it is administered by inhalation. But in making the ether I observed that the first distillation yielded as a product a volatile chloride, of very delicate aromatic odour, and without exception the most perfect general anæsthetic I have ever employed or seen. This compound, of which there is a specimen on the table, is so quick in action that it may be diluted with half its volume of absolute ether, and still yield a vapour of sufficient narcotic power to be available for long or short operations. Exposed

to the vapour, pigeons and rabbits glide into the deepest sleep of unconsciousness without a movement, and in a state more strikingly resembling natural sleep than any other condition; the insensibility may be sustained for two hours without the least apparent danger. Within the last ten days, after first inhaling the vapour myself, I administered it to the human subject, while Mr. Brudenell Carter performed an operation on the eyeball for the cure of strabismus. The action in this instance was simply perfect; the patient subsided into what seemed a natural sleep, without a convulsive or disturbed movement; the operation was performed without the faintest manifestation of sensation, and recovery was perfect in one minute after the vapour was withdrawn*. The experience of the action of the narcotic I have here described is so good that I could not let it pass silently; but I am not yet sure whether the application can be brought into general use. The production of the fluid is troublesome and costly, and after a time, if exposed to the air, it loses its efficacy. In brief, it is not a homogeneous substance, and is therefore open to the objections against compound fluids mentioned in my Report at the Norwich Meeting. The part played by the heavy ether is excellent, in that it equalizes diffusion and prevents pungency of vapour; and I may be able, by further research, to improve the method, or to be guided by what I know of it to some new and better advance; but this I must leave for future research.

The *trimethylic ether* of which I have spoken is a much lighter fluid than the triethylic; it boils at 140° F., and has a vapour-density of 53; but the odour of its vapour is not agreeable, and although it produces safe anæsthesia, it is not perfect in its action.

PART III.—PHYSIOLOGICAL CONSIDERATIONS.

In conducting a lengthened series of experiments such as I have been engaged in carrying out during the past year, many observations, incidental to the work in hand, naturally come before the mind, and to one or two observations of this character I would, for a moment, direct attention in closing the Report.

Consciousness and common sensation.—The metaphysicians, in treating of conscious and unconscious states of mind, have long taught that there may be periods of consciousness with an absence of common sensibility. The truth of this inference is sustained by physical inquiries. In a previous Report on Amylene I pointed out that the vapour of amylene, while it destroys sensation, does not destroy all conscious acts; and in my later observations on the action of methylic ether the same fact has been more perfectly elicited. In several cases where I administered the ether for removing pain in surgical operations, the patients, when quite insensible to pain, were so conscious that they were able to obey every request asked of them; and in some instances were even anxious to reason, stating that they knew what was going on, and arguing that they were not ready for the operation because they were sure they should feel pain. Nevertheless in this state of mental activity they were operated on, and afterwards, while remembering every incident, were firm in their assertion that they felt no pain whatever during the operation. One patient who sat for the extraction of two teeth selected the tooth to be

* During the Meeting of the Association at Liverpool I administered the same vapour to a woman over seventy years of age, while my friend Mr. Walker operated for cataract. The results were as perfect as in Mr. Carter's case.

first extracted, putting her finger to it, and afterwards rearranging her position for the second removal. To the looker on it seemed in fact as though no change in her life had occurred, yet she affirmed that she was sensible of no pain whatever; and several other less striking but hardly less singular examples came before me. We may then, I think, fairly assume that in course of time we shall discover manageable and certain anæsthetic substances which will paralyze sensation only, leaving the muscular power unaltered and the mental little disturbed; and we gather from this either that in the cerebral hemisphere there is some distinct and simple centre of common sensation which may be acted upon by certain agents without involving all the cerebral mass, or that the peripheral nervous matter may be influenced without involving the other portions of the nervous system. On the whole, I incline to the view that the action of those agents which destroy pain before they remove consciousness is primarily on the peripheral system; for we know, from the process of local anæsthesia, that it is easy to destroy sensation at the extremities without destroying or even interfering with consciousness, while those who have inhaled the vapours which destroy common sensation before interfering with the mental condition, invariably describe the experience of a numbness and insensibility in the extreme parts of the body.

That which we medical men most require is an agent that shall be easily applied, and shall admit of being so applied generally as to induce insensibility to pain with or without destruction of consciousness, as the case before us may demand. There are many minor surgical operations for which consciousness need not be destroyed, although pain ought to be; there are other operations in which the consciousness of the person operated upon is of great service to the operator; and there is a third class of cases in which it is essential to suspend both sensation and consciousness.

Now those agents which first destroy common sensation can always be pushed to the extent of destroying consciousness, so that if we could get a perfect agent of the kind we should have the full requirements in our hand. Up to the present moment we have been content with two classes of agents, one which destroys consciousness and sensation at the same time, the other which locally destroys sensation, and has no influence on the consciousness. I look hopefully for a method in which, by means of a single agent, we shall be able at will to suspend common sensation alone, or to exalt the process into suspension of consciousness. When this object is attained, with safety and facility, the science of anæsthesia may be considered as perfected.

Modification of action from physical constitution and construction.—The present series of researches have been specially interesting as showing more clearly in detail the influence of physical constitution and construction of different substances in relation to physiological action. We take, for example, the base ethyl, $C_2 H_5$, and trace out physiological action through its many modifications of compounds. We begin with the hydride of ethyl, $C_2 H_5 H$, and find it an insoluble gas which will produce insensibility if it be made to exclude air from the lungs, but which is, in other respects, negative in action. We pass to the hydrated oxide of ethyl, $C_2 H_6 O$ (alcohol), and find a fluid very soluble in blood, readily diffusible through the body, and producing, when given in sufficient quantity, a prolonged narcotism, with suspension first of common sensation and afterwards of consciousness. We turn to ethyl-ether, $C_4 H_{10} O$, and discover a volatile fluid, soluble to a certain extent in the blood, capable of being absorbed by the lungs, and having the power of producing

quick suspension both of sensation and consciousness. We move to the chloride of ethyl, C_2H_5Cl, and learn that we have in it still a narcotic capable of producing suspension of sensation and consciousness, like ether, but with this difference, owing to the introduction of the new element chlorine, that active convulsive movements are superinduced. We turn to the iodide of ethyl, C_2H_5I, to observe again a narcotic action, as with ether, together with irritation and overaction of secreting glands, owing in this instance to the introduction of the element iodine. We take up the bromide of ethyl, C_2H_5Br, to discover an excellent narcotic, but one which, owing to the introduction of bromine, causes dryness of mucous membrane. Lastly, we turn to nitrite of ethyl, $C_2H_5NO_2$, and experimenting with it learn that with the introduction of the element nitrogen we lose much of narcotic action and gain an agent which, being introduced into the body, reduces the sympathetic nervous power, lets loose the heart so that it can deliver its blood into enfeebled vessels, allows excreting organs, such as the kidneys, to pour forth an abundant secretion, and which, carried far enough, paralyzes muscular action so effectually as to overcome even tetanic spasm.

I point out these simple truths in order to indicate once again the correct line of research in reference to all substances used as medicines. To commence with a base and to follow the modifications of its action through the varied compounds formed upon it, that, as it seems to me, is the only method by which the physiologist can arrive at positive truth in his classification and selection of remedies for the diseases that afflict mankind.

Direct action of agents on nervous centres.—The teachings of the last half century have led us to the theory, now generally accepted, that all chemical agents, in order to produce an effect on the body, must enter the blood and be carried by it through the organism. It is true that Dr. Wilson Philip demurred to this, and showed that alcohol would influence the heart immediately when brought into contact with the cerebrum; and it is also true that Dr. John Jones observed, in his experiments on young alligators, that the act of respiration could be instantly suspended by applying hydrocyanic acid directly to the medulla oblongata. Still the theory remained in force, the argument being that the substances applied to the nervous matter were rapidly absorbed into the circulation. My own observations on nitrite of amyl have, however, assured me that one agent, at all events, may act directly on nervous matter. To prove this, an animal was allowed to sleep into death in the vapour of bichloride of methylene, and all the blood-vessels leading to and from the heart were firmly tied, so as to cut off every possibility of circulation of blood into or out of the heart; then with a subcutaneous injecting syringe, through the optic foramen, five grains of nitrite of amyl were introduced into the cavity of the skull, so as to bring the agent in contact with the cerebral mass. Instantly the heart, which had continued pulsating, ceased for a moment, and then recommenced action with the same extreme rapidity as is observed in the living animal subjected to the influence of the vapour of the nitrite. I repeated the experiment twice with the same result, the rapid cardiac action continuing from two to three minutes in each case. These experiments lead me to suggest that we have accepted too readily the idea of the necessity of absorption of all chemical substances for the production of physiological effects, and that we ought to go back to an old subject of inquiry, the direct action of chemical and physical agents upon nervous matter. When we irritate the extremities of a nerve, as, for instance, when we inhale strong ammonia or particles of snuff, and excite muscular action, or when we call forth sensation, as when we take in the odour of

flowers or musk, we never consider the question of absorption by the blood, but attribute the phenomena that follow to a superficial influence exerted upon the periphery of nerve. The question is, whether with certain other agents a more extended influence may not be exerted through the nervous structures so that the nervous centres themselves may be impressed and systematic derangements be excited by the disturbance. If this be proved to be the fact in respect to known organic bodies, such as nitrite of amyl, it may be worth while to carry out the same line of inquiry in the investigation of those obscure diseases which we attribute to minute particles of organic poisons, and which are invariably heralded by symptoms indicating changes, of function, at least, in the nervous centres that govern those organs by the action of which the natural life of the body is sustained.

In concluding this Report, I have once more to claim your indulgence for all its shortcomings. I claim to be, as it were, a mere gardener in the field of physiological medicine. The physicist and the chemist give seeds which I and a few others plant in our domain. We take the offering, try its value, and then there follow accomplished scholars and practitioners who join with us in proving and establishing the practical results and benefits that are to succeed upon the primary research. The labourers in the primary research are not unfrequently forgotten for a time, as their followers gather their produce and weave it into forms that attract and please the world. But our satisfaction is none the less complete as we witness the development of our efforts, since the solid satisfaction lies, not in the promise of the sowing, but in the proof of the reaping. I have thanked this Association many times for having recognized the importance of the primary exertion to which I refer, and in thanking it once more I hold myself at its disposition to continue at my tasks under its sympathetic and powerful influence. It is true that by what is called private industry one may do much to advance any profession, if to the advancement the mind be simply and sincerely devoted; but when one expends industry, as I have been allowed to expend it, by the direction of this convocation of men of all sciences, the effect is tenfold in weight and measure. The effort is accepted away from these meetings because it has been accepted in them, and the science of medicine is strengthened because she marches with the other sciences in mutual understanding and for mutual progress.

Report of the Rainfall Committee for the Year 1869–70, *consisting of* C. BROOKE, *F.R.S.* (*Chairman*), J. GLAISHER, *F.R.S.*, Prof. PHILLIPS, *F.R.S.*, J. F. BATEMAN, *C.E.*, *F.R.S.*, R. W. MYLNE, *C.E.*, *F.R.S.*, T. HAWKSLEY, *C.E.*, Prof. ADAMS, *F.R.S.*, C. TOMLINSON, *F.R.S.*, Prof. SYLVESTER, *F.R.S.*, Dr. POLE, *F.R.S.*, ROGERS FIELD, *C.E.*, *and* G. J. SYMONS, *Secretary*.

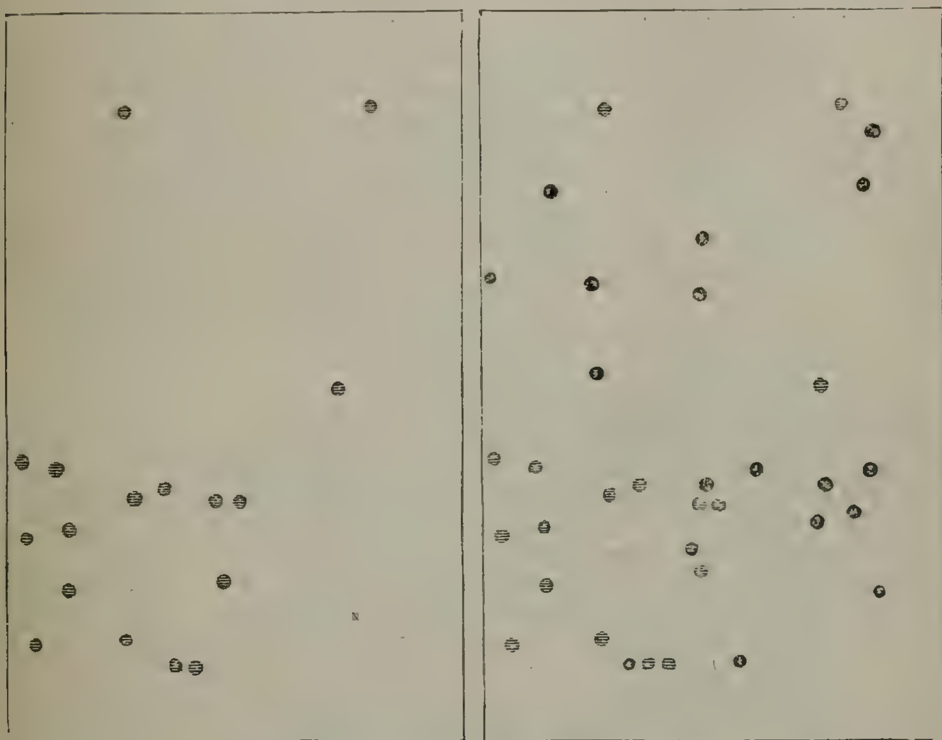
IN our last Report we reprinted the rules which had been issued for the guidance of observers, and we also expressed the opinion that a considerable addition to the staff in several districts was desirable. This proposal was approved by the General Committee at Exeter, and a small sum granted towards the expenses which would be incurred.

One of the districts very destitute of observers was Dartmoor, and thither

accordingly our Secretary proceeded, in order to obtain such further observers as seemed requisite. In this he was on the whole very successful, as the accompanying diagram shows more clearly than any explanation.

Rain-gauge Stations in Devonshire (part of).

1869. 1870.



Old Stations. Old and new Stations.

Great, however, as was the improvement then effected, it cannot be said that the rainfall of Dartmoor is properly observed until gauges have been started, one near Cranmere Pool and one between Meavy and Holne, two districts extremely difficult of access and quite uninhabited.

Subsequently circulars were sent to (and courteously inserted in) 'The Times,' 'Nature,' 'Scientific Opinion,' and various local journals in districts where observers were most required. About 100 volunteers were thus obtained, many of whom also undertook to pay for their own instruments, thus materially increasing the number of stations obtained by our special grant. Gauges, the property of this Association, have been supplied to the following stations during the past year, and, with hardly an exception, the returns sent in have been most satisfactory:—

Country.	County.	Station.	Observer.
England	Devon	Tavistock Reservoir	Mr. Merrifield.
„	„	Clawton, Holsworthy	W. W. Melhuish, Esq.
„	„	Prison Garden, Dartmoor	Mr. Watts.
„	„	Rundles Cross, „	„
„	„	Powder-Mills, „	Mr. Henwood.
„	„	Holne Vicarage, „	Rev. J. Gill.
„	„	Oaklands, Oakhampton	W. H. Holley, Esq.
„	„	N. Lew, Hatherleigh	Rev. T. England.

Country.	County.	Station.	Observer.
England	Nottingham	Grove Ho., Mansfield	R. Tyrer, Esq.
,,	Yorkshire	Malham Tarn, Bell Busk	W. Bissett, Esq.
,,	,,	Askrigg	Mr. A. Knaggs.
,,	,,	Pateley Bridge	E. Warburton, Esq.
Wales	Carmarthen	Llangadock	F. Layard, Esq.
Isle of Man	Isle of Man	Kirkmichael	Rev. W. C. Ingram.
Scotland	Aberdeen	Cairnbanno, New Deer	Mr. W. Adie.
,,	,,	Forgue, Huntley	Rev. J. Abel.
,,	Argyll	Ballachulish	Rev. D. Mackenzie.
,,	Ayr	Holehouse, Patna	Mr. P. Murdoch.
,,	Banff	Inchrory, Tomintoul	Mr. A. MacRae.
,,	Fife	Auchtermuchty	F. Troup, Esq., M.D.
,,	Inverness	Sligachan, Portree	Mr. McDonald.
,,	,,	Budgate, Cawdor	J. Joss, Esq.
,,	Lanark	Iron-works' School, Muirkirk	Mr. J. Wilson.
,,	Nairn	Auldearn	Mr. Laidlaw.
,,	Ross	Strathconan	C. J. Smith, Esq.
,,	,,	Gairloch	Mr. A. Davidson.
Ireland	Antrim	Carrickfergus	A. Sutherland, Esq.
,,	Galway	Ballinasloe	J. Kempster, Esq.
,,	Kerry	Cara Lake, Killarney	J. B. Kennedy, Esq.
,,	,,	Darrynane, Cahirciveen	D. O'Connell, Esq.

While upon this subject, your Committee may point out that if a corps of amateur observers, sufficient for rainfall purposes, say, 1500 to 2000 in number, is to be kept together, a regular and considerable number of new ones must annually be obtained, to supply vacancies produced by death and removals. Your Committee, being fully convinced of the great and increasing importance of accurate registration of the fall of rain, will at all times be glad to receive, through their Secretary (G. J. Symons, Esq., 62 Camden Square, London), offers of assistance from residents in the less densely peopled parts of the British Isles. The instrument now used is extremely simple and inexpensive.

Your Committee have always regarded the examination of the gauges in use, of their positions, and the personal communication between their Secretary and the various observers as a matter of the highest importance. They have, therefore, much pleasure in announcing that upwards of one hundred stations have been visited during the past year. The various suggestions offered by the Secretary have been most cheerfully adopted by the observers, who often warmly express their approval of this inspection, both for its own sake and as tending to secure uniformity of practice, and to increased *esprit de corps* among the observers.

Full details of the results of the examinations in 1869–70 are given in the Appendix. The number of stations examined in the respective counties was as follows:—

Berkshire	2
Cornwall (including Scilly)	43
Devon	32
Hampshire	1
Kent	7
Norfolk	2
Suffolk	6
Surrey	2
Montgomery	7
Radnor	2

We regret having been unable to take any steps during the past year to-

wards the collection of old observations. It is a most desirable object, and without it our other work will not be complete; but our Secretary has not time for it, and we have not funds to provide a regular copyist.

In our last Report we gave an analysis of the results of the experimental gauges employed at Calne to determine the relative indications of gauges of various sizes.

We now give a similar discussion of the series erected to test the influence of elevation above the ground on the amount collected. It had long been known that gauges *on buildings* collected considerably less than those on the ground, this branch of the inquiry having many years ago been examined with great care by Prof. Phillips. As his experiments and results are printed in the 3rd, 4th, and 5th Reports of this Association, it is unnecessary here to give more than a brief *résumé* of the whole. Prof. Phillips had three similar gauges, one placed in the gardens of the York Museum, one on its roof, and one on a pole 9 feet above the battlements of the great tower of York Minster. The heights of these gauges, the total amounts collected, and their ratios are given in the following Table:—

		Ground.	Museum.	Minster.
		ft. in.	ft. in.	ft. in.
Height	Above ground	0 2	43 8	212 10
,,	,, high water	29 0	72 8	241 10
		in.	in.	in.
Amount of rain.	Total of 12 months, 1832–33	23·79	20·18	15·72
	,, ,, 1833–34	25·71	19·85	14·96
	,, ,, 1834–35	15·94	12·14	8·29
	,, for 3 years	65·44	52·17	38·97
Ratio.	1832–33	100·0	85·3	66·1
	1833–34	100·0	77·2	58·2
	1834–35	100·0	76·1	52·0
	3 years	100·0	79·7	59·6

We need hardly remark that, owing to the labour of ascending to the top of the Minster, the observations were not taken daily, but about once a month. The result of a series of calculations was to indicate that the normal rate of decrease was not very far from $3\sqrt{h}$, but that both the actual amount and the ratios were dependent on temperature.

The Calne experiments, of which we are now going to give a brief account, differed from those of Prof. Phillips, both in their object and their details. At York the object seems to have been to determine the causes of the different amounts collected; at Calne it has been to ascertain the precise differences, and the possibility, or otherwise, of deducing corrections whereby observations made at various *small* heights above the ground may be reduced to one common standard. Hence the gauges were mounted on posts, not on roofs; the greatest height was 20 feet instead of 210 feet, and the readings were taken daily instead of monthly. It may be expedient, before proceeding further, to illustrate by an example the necessity for this correction—(1) on account of its extent, (2) on account of the very various heights at which gauges are placed. Taking haphazard a single page of *British Rainfall*, which contains returns from 44 stations, we find just 22 different heights, viz.:—

Stations.	Height. ft.	in.	Stations.	Height. ft.	in.	Stations.	Height. ft.	in.
2	0	4	1	1	3	1	4	4
3	0	6	1	1	10	3	4	6
1	0	7	1	2	0	1	5	8
1	0	8	1	2	6	3	6	0
3	0	10	3	3	0	1	6	6
1	0	11	1	3	2	2	16	6
9	1	0	1	3	6			
3	1	1	1	4	2			

We could hardly have stronger evidence of the necessity for uniformity in placing new gauges. Old gauges, however, must not be moved; therefore it is necessary to ascertain the correction for these various heights, and hence the following Tables. But we have not yet hinted at the amount of the correction; it will be presently shown that, within the above-quoted limits, viz. from 4 inches above the ground to 16 feet 6 inches, the amount collected will differ by 10 per cent.

The gauges employed in the Calne elevation experiments were in number ten, in shape that known as "Glaisher's," 8 inches in diameter, and in general features identical; they were all constructed by Messrs. Negretti and Zambra, and remarkably accurate. They were placed at the following heights:—Level with turf, 2 inches, 6 inches, 1 foot, 2 feet, 3 feet above it: these were all exactly like fig. 1, the last two standing on dwarf

Fig. 1.

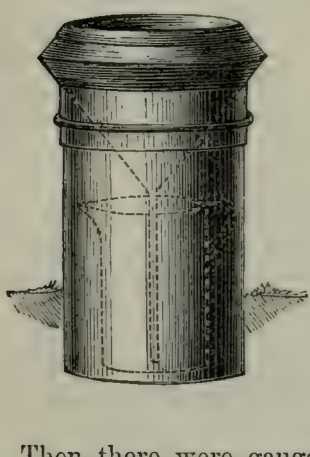
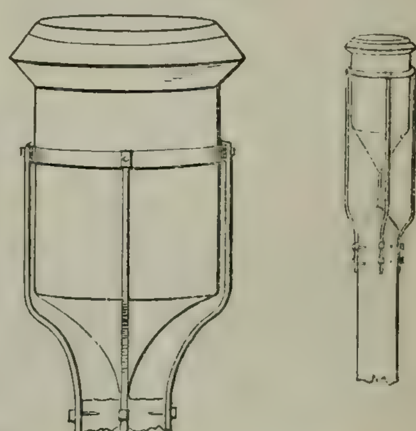


Fig. 2.

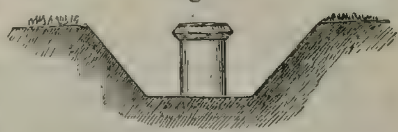


posts. Then there were gauges, like fig. 2, at 5 feet, 10 feet, and 20 feet above the ground, supported on posts, into which a piece of gas tubing was inserted (as lead in a cedar pencil), down which the water passed into bottles at a conveniently accessible height. As objection may possibly be taken to this arrangement, on the ground of loss by evaporation, we may state that it was not adopted until repeated experiments had proved that the loss was almost inappreciable, even with delicate instruments. At 20 feet two gauges were placed, one 8 inches and one 5 inches in diameter; as it appears that the diminution is not the same for 5-inch as for 8-inch gauges, we shall not for the present discuss specially the observations with this gauge. During the first four years the whole of the gauges were read daily; during 1867

they were purposely read only once a month, in order to ascertain if any material difference would be detected.

Gauges whose mouths are level with, or near to, the surface of the ground are always found to collect more or less of the soil surrounding them, which is splashed up by heavy rain and collected in the gauge. Rain-gauges are usually so constructed that very little, if any, rain which falls within their receiving area shall splash out and escape. Hence it seems probable that gauges nearly level with the surrounding soil will always collect the true rainfall, *plus* insplashing. As a means of eliminating this source of error, another gauge, of the same pattern as the others, was added to the series in April 1865; it was sunk in a pit, the depth of which was equal to the height of the gauge, and with sloping sides, as in fig. 3. By this means the receiving surface was exactly level with the ground, and insplashing was impossible. This gauge will be called the pit-gauge.

Fig. 3.



These, then, are the instruments wherewith, and the conditions under which, the observations at Calne were taken. We may now introduce some of the results, *some* only, for the observations are so voluminous and complete as to be almost inexhaustible.

Table I. contains the total amount collected in each gauge in each month, from August 1863 to December 1867, both inclusive.

Table II. contains these monthly totals converted into ratios, the amount measured in the gauge whose receiving surface is *one foot* above the surface being taken as unity.

Table III. is exactly similar, except that the "pit-gauge" (fig. 3) is taken as unity.

Table IV. contains the total fall in each year and in the whole period; also these values reduced to the ratios of the 1-foot gauge.

Table V. contains the 1-foot ratios, grouped according to months.

Table VI. contains the mean monthly values deduced from Table V.

Table VII. contains the mean monthly values deduced from Table III.

Table VIII. contains the monthly (1-foot) ratios for 1864 and 1865, grouped according to the *mean temperature* of the days in each month on which rain fell.

Table IX. is similar, but grouped according to the *hygrometric condition of the atmosphere* on those days.

Table X. is similar, but grouped according to the *mean velocity of the wind**.

It is hoped that this series of Tables is so complete as to render lengthened remarks unnecessary.

We have already referred to the pit-gauge, we may now point out its result, viz. that in the winter it catches very much less than the one surrounded by grass; and that though in summer both catch alike, on the average of the year the pit-gauge is 3 per cent. less than the "level," and agrees almost exactly with the one whose orifice is 2 inches above the ground. This agreement of the "pit-gauge" and the "2-inch" seems to show that the amount collected by gauges thus placed is correct. The accompanying diagrams (Plate V.) show the mean monthly and annual deficiencies therefrom of gauges at various heights above the ground.

* In the formation of the last three Tables some calculations by Dr. Barter of Bath have been very useful.

In order that the proportion which the altitudinal deficiency bears to the total rainfall may be readily seen, the annual diagram represents, by light shading, the actual fall at various heights above the ground; the amount collected by the "pit-gauge" is shown by the horizontal line of 1·000, and the deficiency in the upper gauges by the breadth of darker shading.

In the monthly diagrams, the variable breadth of this darker shading shows the variation of this altitude correction with the seasons.

Probably the most remarkable features in the annual curve are:—(1) its rapid curvature, *i. e.* rapid increase in the amount of rain collected within 1 foot of the surface of the ground; (2) the very slight alteration from about 7 feet to 20 feet.

This would seem to show that the rainfall actually reaching the ground is greater than what has hitherto been supposed, inasmuch as the majority of gauges hitherto erected have their orifice about 1 foot above the ground, and therefore collect, according to the results now before us, about 5 per cent. *less* than the real rainfall reaching the ground. This result appears so startling that further experiments will be conducted on the subject.

The difference between the curves of decrease in the various months is very considerable, and sufficiently proves that the annual mean values are not at all applicable to single months.

Tables VIII., IX., and X. seem to show that the variation is in no way dependent on the humidity of the air, but either on temperature or wind-force, or possibly on radiation; the present investigation does not reveal which, inasmuch as the cold days, with rain, are usually windy ones.

Our duty in connexion with this subject is discharged by Tables VI. and VII., which give (for 8-inch gauges) the means of deducing the fall, either at the surface of the ground or at 1 foot above it, from observations of gauges on pedestals or pillars at any height less than 20 feet.

Perhaps it may be well to give an example. At Cockermouth there are two gauges, one 6 inches and the other 6 feet 6 inches above the ground; in the year 1869 they collected 46·31 and 44·48 respectively: the corrections from Table VII. are ·969 and ·920; then we have:—

Gauge 6 inches above ground $=46{\cdot}31 \div {\cdot}969 = 47{\cdot}79 =$ ground fall.
,, 6 feet 6 inches ,, $=44{\cdot}48 \div {\cdot}920 = 48{\cdot}34 =$,,

Or if we require the 1-foot fall, then the corrections from Table VI. are 1·014 and ·960; then we have:—

Gauge 6 inches above ground $=46{\cdot}31 \div 1{\cdot}014 = 45{\cdot}67 =$ fall at 1 foot.
,, 6 feet 6 inches ,, $=44{\cdot}48 \div {\cdot}960 = 46{\cdot}33 =$,,

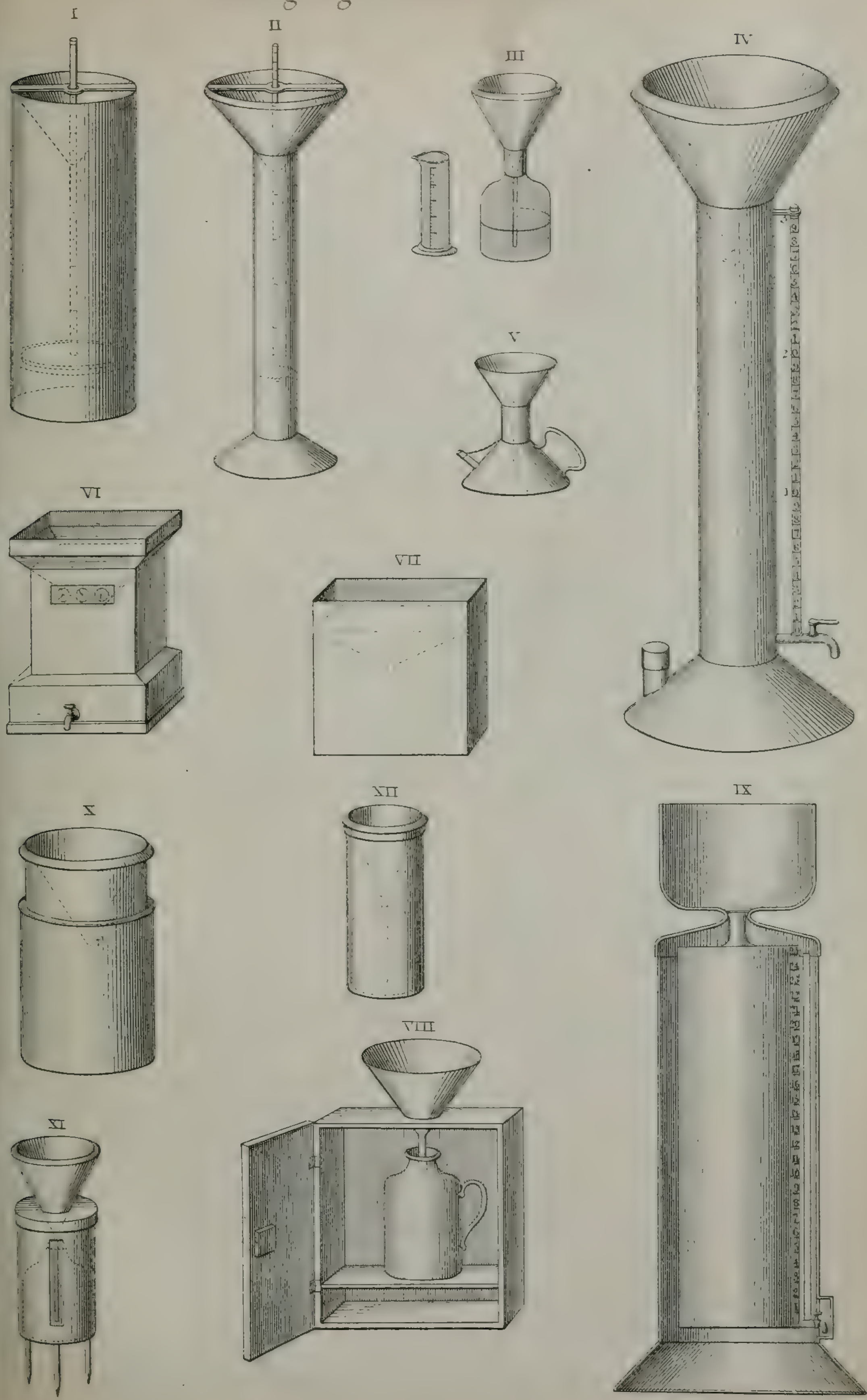
This example was taken quite by chance, and the agreement being in both cases within $1\frac{1}{2}$ per cent., seems to show that the corrections are generally applicable. But on this point we have at present no evidence.

The inquiry we have just been pursuing naturally leads to the consideration of the best height for rain-gauges; and, although a novel plan, we are inclined to consider that, theoretically, the "pit-gauge" is the best. But there are several strong grounds of objection to it and to all gauges whose orifices are nearly level with the soil. We may mention a few:—

1. They become more or less filled with leaves during the autumn months, and their accuracy is thereby vitiated.

2. They become buried under snow, and the melting snow runs unfairly into them.

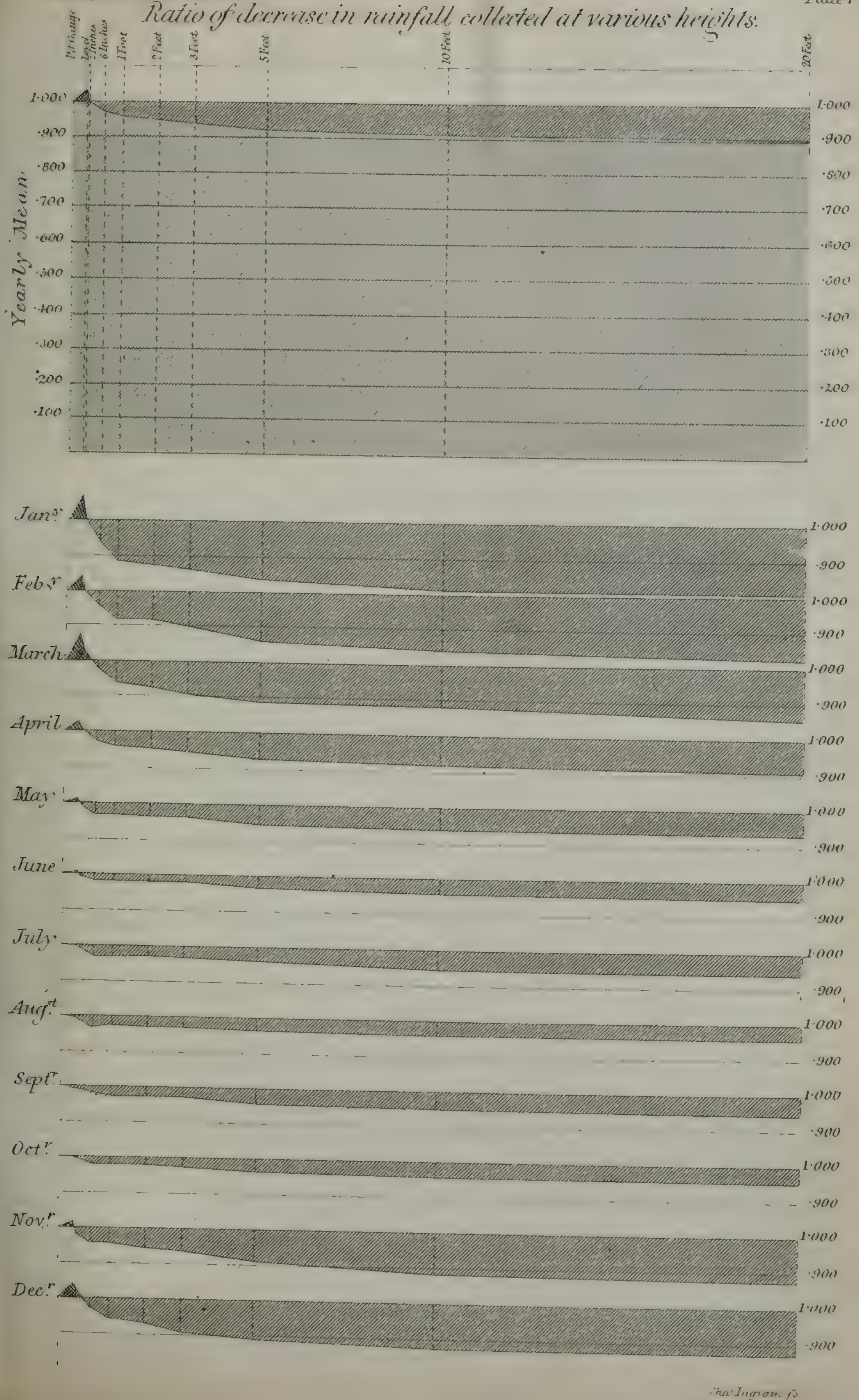
Rain gauges in use in 1866.



Inches 12 6 0 1 2 3 Feet

J. W. Lowry fc.

Ratio of decrease in rainfall collected at various heights.



3. In cases of *extremely* heavy rain they collect water running along the surface of the ground, and sometimes become filled, at others float away on the water.

4. They are more liable to accidental injury, and to collect all kinds of rubbish than if slightly elevated.

5. It is evident, from the Tables, that an error of 1 inch in the height of a gauge near the surface is of as much importance as an error of 1 foot at a slight distance above it.

Moreover, it must be remembered that up to the present time not half a dozen pit-gauges have been used, and that therefore their adoption would involve the correction of all observations hitherto made.

And that though it appears probable that the rainfall actually reaching the ground is nearly 5 per cent. greater than what has hitherto been supposed, it would be precipitate to accept it without further examination.

As nearly half the gauges in the country are now fixed, with their receiving surfaces, 1 foot above the ground, it would appear desirable that this height should be generally adopted.

In several previous Reports we have given the results of elaborate investigations of the percentage of rain falling in the various months in different parts of the British Isles; these Tables uniformly referred to decennial periods, such as 1810–19, 1820–29, 1830–39, 1840–49, 1850–59. We have therefore recently completed another decade, and one of which the returns are much more complete than for any of its precursors. The computations of the mean monthly and annual rainfall during this period are in progress, but they are so heavy that they cannot be ready for this Report, and may perhaps not be completed for the next.

We give in the Appendix the usual detailed Tables of monthly fall at about 300 stations during the two years 1868–69, but we defer any remarks upon them until the averages are ready next year.

Your Committee cannot close their Report without drawing attention to the remarkable illustration of widespread interest in scientific pursuits afforded by the fact that there are now nearly 2000 persons in the British Isles regularly recording the fall of rain, and carefully watching any departure from its normal distribution. Of the utility of this work, in a populous and manufacturing country like ours, it is needless to speak; but we may mention that other nations and our own colonies are copying our system, and that for water-works, canal, mill, and agricultural purposes rainfall information is yearly more and more required.

The services rendered by the observers are (with but a very few exceptions) entirely gratuitous, nay more, the observers themselves have to defray the cost of printing the results of their labours.

Considering that it is demonstrably a matter of national interest that this organization should be made as permanent as possible, we cannot help thinking that it would be a graceful and economical act were Government to offer to relieve the observers from the cost of reducing and printing their returns. A few hundreds annually would probably suffice to hold together a body of practised observers which has no equal in the world, and which, once broken up, could not be replaced; since, irrespective of the difficulty of training new observers, the continuity of the old observations would be destroyed.

TABLES OF MONTHLY RAIN-

ENGLAND.

	Division I.—Middlesex.								Div. II.–S.E. Counties.			
	Middlesex.								Surrey.			
Height of Rain-gauge above	Camden Town.		Upper Clapton.		Hampstead.		Bittacy House, Mill Hill, Hendon.		Dunsfold, Godalming.		Weybridge Heath.	
Ground	0 ft. 4 in.		2 ft. 6 in.		1 ft. 0 in.		1 ft. 0 in.		2 ft. 6 in.		0 ft. 6 in.	
Sea-level......	111 ft.		90 ft.		385 ft.		420 ft.		166 ft.		150 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	3·89	2·76	3·61	2·48	3·84	2·72	3·17	2·95	3·93	3·43	4·04	3·34
February ...	1·21	2·48	·80	2·36	1·40	2·64	1·50	2·52	1·24	2·84	1·08	2·54
March	1·28	1·97	1·66	1·59	1·45	1·95	1·62	1·94	1·25	1·40	1·49	1·05
April	1·50	1·28	1·58	1·22	1·67	1·41	1·62	1·57	2·23	1·13	1·65	1·49
May	1·58	3·27	1·26	3·00	·93	2·99	·89	3·62	·72	5·11	·90	3·83
June	·78	1·03	·60	1·02	·67	1·14	·48	1·00	·50	1·19	·65	1·28
July	·45	·62	·41	·64	·44	·90	·60	·93	2·42	·87	2·59	·90
August	2·28	1·26	2·64	1·43	2·93	1·50	3·56	1·35	4·12	1·43	2·58	1·37
September ...	1·74	3·56	1·46	3·27	2·27	3·38	2·56	4·02	2·32	4·55	1·92	4·38
October	2·54	1·87	2·87	1·89	2·76	1·89	2·66	1·77	2·56	1·77	2·35	1·76
November ...	1·03	2·38	·91	2·37	·97	2·28	1·41	2·35	1·31	1·84	1·32	2·37
December ...	5·12	2·94	4·79	2·77	5·63	3·08	5·77	3·72	7·02	3·42	5·39	2·74
Totals	23·40	25·42	22·59	24·04	24·96	25·88	25·84	27·74	29·62	28·98	25·96	27·05

	Division II.—South-Eastern Counties (*continued*).											
	Kent (*continued*).						Sussex.					
Height of Rain-gauge above	River Head, Sevenoaks.		Acol, Margate.		Sidcup, Foots Cray.		Brighton Water Works.		West Thorney.		Chichester Museum.	
Ground	1 ft. 0 in.		1 ft. 0 in.		0 ft. 7 in.		1 ft. 0 in.		1 ft. 0 in.		0 ft. 6 in.	
Sea-level......	520 ft.		60 ft.		....		90 ft.		10 ft.		50 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	6·37	4·05	2·85	1·79	3·68	2·92	3·53	2·74	3·40	3·18	3·05	2·91
February ...	1·85	3·65	1·17	2·97	1·37	2·40	2·42	2·83	1·25	2·18	1·03	1·84
March	1·79	2·80	1·10	2·12	1·60	1·66	1·32	2·25	1·60	2·30	1·41	1·72
April	2·83	1·89	1·51	1·74	1·54	1·21	2·46	1·31	2·22	1·22	2·25	1·06
May	·80	4·26	1·12	2·24	·57	3·90	1·67	4·34	1·02	3·63	·91	4·31
June	·50	1·53	·89	·75	·33	1·36	·76	1·30	·48	2·11	·69	1·64
July	1·44	·58	·72	·29	·58	·59	1·71	·16	·82	1·52	·81	1·09
August	3·42	1·42	2·34	1·07	2·47	·96	3·74	1·70	4·64	·54	3·57	·59
September ...	2·52	5·79	1·81	1·75	2·50	3·47	·85	3·79	2·95	2·53	2·80	4·83
October	2·97	2·92	1·69	2·22	2·03	1·43	4·53	2·90	3·16	1·76	3·41	2·29
November ...	2·06	3·45	2·05	1·64	1·10	2·73	1·24	2·61	1·41	1·53	1·38	1·86
December ...	8·27	5·00	4·26	2·02	4·42	2·77	7·55	3·81	7·93	2·28	7·30	3·21
Totals	34·82	37·34	21·51	20·60	22·19	25·40	31·78	29·74	30·88	24·78	28·61	27·35

FALL IN THE BRITISH ISLES.

ENGLAND.

Division II.—South-Eastern Counties (*continued*).

Surrey (*continued*).						Kent.							
Bagshot Park.		Kew Observatory.		S. Fields, Wandsworth.		Dover.		Horton Park, Hythe.		Linton Park, Staplehurst.		Tunbridge.	
1 ft. 1 in. 130 ft.		1 ft. 3 in. 19 ft.		1 ft. 0 in. …………		2 ft 2 in. 16 ft.		1 ft. 4 in. 350 ft.		0 ft. 6 in. 296 ft.		1 ft. 0 in. 71 ft.	
1868	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
4·30	1·94	3·35	2·30	4·00	2·75	4·58	2·80	3·84	2·79	3·65	3·04	3·70	3·27
·69	1·98	1·08	1·94	1·20	2·40	1·37	2·95	1·37	2·38	1·35	3·15	1·00	3·25
2·19	·66	·95	1·06	1·15	1·45	1·45	3·52	1·49	3·50	1·29	2·91	1·91	2·46
2·09	1·34	1·48	1·26	1·55	1·25	1·97	2·58	1·92	1·91	1·21	1·33	2·04	1·82
·68	2·86	·77	3·06	1·40	2·93	1·77	3·95	1·29	3·86	1·92	3·78	·76	4·04
·57	·70	·43	1·04	·45	1·30	·73	·90	·71	1·25	·51	·87	·43	·98
2·02	·62	1·62	·88	1·55	·77	·85	·34	1·18	·32	·63	·32	1·71	·15
2·51	1·43	2·52	1·17	2·65	1·80	4·32	1·78	4·48	2·79	2·30	1·16	3·50	1·21
1·96	3·78	2·24	3·75	1·55	3·70	1·67	3·21	2·52	3·32	2·70	3·81	1·91	3·73
2·35	1·26	2·27	1·44	2·50	1·83	3·55	1·93	2·83	2·04	2·07	2·79	2·02	2·78
1·07	2·19	·92	2·27	1·18	2·00	2·41	2·09	2·81	2·62	1·78	2·14	1·89	2·79
4·85	2·77	5·20	2·46	5·25	2·15	6·31	4·45	6·74	4·11	5·78	3·79	6·10	3·61
25·28	21·53	22·83	22·63	24·43	24·33	30·98	30·50	31·18	30·89	25·19	29·09	26·97	30·09

Division II.—South-Eastern Counties (*continued*).

Sussex (*continued*).												Hampshire.	
Bleak House, Hastings.		Dale Park, Arundel.		Battle.		Chilgrove, Chichester.		Balcomb Place, Cuckfield.		Petworth Rectory.		St. Lawrence, Isle of Wight.	
1 ft. 3 in. 80 ft.		4 ft. 0 in. 316 ft.		1 ft. 3 in. …………		0 ft. 6 in. 284 ft.		1 ft. 3 in. 340 ft.		1 ft. 10 in. 190 ft.		1 ft. 0 in. 75 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·44	2·42	4·23	3·22	4·56	3·23	4·34	3·51	5·09	3·94	4·92	4·13	4·00	3·46
1·05	2·27	1·28	3·27	1·17	2·24	1·53	2·91	1·39	3·80	1·74	3·50	1·08	2·58
1·20	1·90	1·88	1·35	1·56	2·25	2·06	2·80	1·39	1·72	1·91	1·43	1·27	2·60
1·72	1·30	2·11	1·13	2·14	1·49	2·61	1·10	2·39	1·71	3·08	1·24	3·14	1·11
·76	4·59	1·21	4·75	1·07	4·61	1·20	4·42	1·08	3·56	·98	4·91	1·30	4·72
·51	·69	·86	1·52	·57	·79	·61	1·95	·54	1·67	·41	1·78	·54	2·15
2·54	·26	1·04	·80	2·01	·31	·93	1·15	2·46	·36	1·64	·77	·68	1·17
4·15	1·70	3·87	1·05	3·83	2·03	4·81	1·55	2·78	1·38	4·22	·99	4·36	·98
1·02	3·20	3·94	5·35	2·33	4·51	3·43	6·00	2·72	5·45	4·44	5·61	2·56	4·19
2·80	1·79	4·06	4·11	3·61	2·07	4·01	2·31	2·74	2·98	3·31	2·06	3·72	2·27
1·67	2·17	1·43	·84	1·80	2·55	1·64	2·47	1·50	2·85	1·72	2·14	1·37	2·00
5·36	3·31	8·86	3·25	6·79	4·17	8·96	4·21	8·38	4·46	9·00	4·55	7·31	3·71
26·22	25·60	34·77	30·64	31·44	30·25	36·13	33·38	32·46	33·88	37·37	33·11	31·33	30·94

ENGLAND.

Division II.—South-Eastern Counties (*continued*).

Hampshire (*continued*).

Height of Rain-gauge above	Ryde, Isle of Wight.		Osborne, Isle of Wight.		Fareham.		Shirley Warren, Southampton.		Selborne.		Liss, Petersfield.	
Ground …… Sea-level……	7 ft. 0 in. 15 ft.		0 ft. 6 in. 172 ft.		0 ft. 2 in. 20 ft.		4 ft. 0 in. 106 ft.		4 ft. 0 in. 400 ft.		0 ft. 8 in. …………	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ……	4·52	4·00	3·68	3·32	3·77	3·67	4·14	3·90	5·73	4·53	7·45	6·25
February …	1·40	2·52	1·50	2·79	2·09	2·73	1·62	2·06	2·19	3·33	2·48	3·60
March ……	1·48	2·70	1·68	2·18	1·97	2·00	1·59	1·72	2·21	1·93	3·04	1·89
April ………	3·02	·99	2·75	·98	3·02	1·41	3·24	1·10	2·85	1·26	3·89	1·36
May ………	1·16	4·84	1·25	4·38	1·54	5·48	1·71	4·33	1·59	4·68	2·09	4·88
June ………	·40	2·27	·54	2·78	·59	2·08	·73	1·66	·46	1·81	·27	1·76
July ………	·77	2·15	·52	1·14	·57	1·18	·65	·91	1·74	·97	1·10	1·20
August ……	5·21	·61	4·68	·60	5·43	·83	4·61	·86	3·89	1·49	4·88	1·63
September …	2·98	6·26	3·82	5·82	1·19	4·68	4·50	5·54	4·48	6·39	3·23	7·12
October ……	3·26	2·40	3·00	2·25	5·54	3·42	2·73	2·14	3·41	2·21	3·72	2·50
November …	1·46	1·58	1·50	1·64	1·59	1·39	1·75	1·46	2·44	2·55	2·94	2·61
December …	7·45	4·33	7·82	4·03	8·70	3·65	8·22	4·36	8·54	4·72	10·69	5·82
Totals ……	33·11	34·65	32·74	32·41	36·00	32·52	35·49	30·04	39·53	35·87	45·78	40·62

Division III.—South Midland Counties (*continued*).

	Buckinghamshire.		Northampton.				Bedford.		Cambridge.			
Height of Rain-gauge above	High Wycomb.		Althorpe House.		Wellingborough.		Cardington.		Wisbech.		Mid-level Sluice, Outwell.	
Ground …… Sea-level……	0 ft. 9 in. 225 ft.		3 ft. 4 in. 310 ft.		0 ft. 8 in. …………		0 ft. 0 in. 100 ft.		8 ft. 0 in. 18 ft.		4 ft. 0 in. 16 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ……	3·66	3·24	2·30	3·22	2·63	2·64	2·80	2·50	1·62	1·85	1·01	1·35
February …	1·58	2·00	1·62	2·16	1·05	2·07	1·50	1·80	1·39	2·20	·92	2·23
March ……	1·82	1·39	1·78	1·20	1·67	1·56	1·64	1·30	1·54	1·90	1·31	2·25
April ………	1·72	1·86	1·65	1·46	1·14	1·95	1·13	1·75	1·45	1·63	1·13	1·79
May ………	·69	3·16	·72	4·29	·44	4·05	·60	3·50	·31	3·51	·11	2·68
June ………	·55	1·57	·45	1·85	·71	1·29	1·00	1·15	·52	1·60	·53	1·22
July ………	1·50	1·52	·26	·29	·14	·30	·15	·30	·56	·44	·33	·63
August ……	3·55	1·63	3·23	·96	2·64	·96	3·20	·82	2·89	2·08	1·98	1·76
September …	3·21	3·94	3·31	3·78	2·30	3·01	3·20	2·25	2·41	3·16	2·40	3·34
October ……	2·87	1·34	2·02	1·25	2·41	·94	2·40	1·00	2·86	1·27	2·45	1·19
November …	1·16	2·52	1·90	2·21	1·34	2·02	1·20	2·00	1·19	1·94	1·07	1·75
December …	5·00	3·77	4·46	3·52	4·28	3·48	3·12	2·88	4·94	3·91	3·40	2·97
Totals………	27·31	27·94	23·70	26·19	20·75	24·27	21·94	21·25	21·68	25·49	16·64	23·16

ENGLAND.

Division II.—South-Eastern Counties (continued).				Division III.—South Midland Counties.									
Hampshire (continued).		Berkshire.		Hertfordshire.						Oxford.			
Aldershot.		Long Wittenham.		Berkhempstead.		Royston.		Hitchin.		Radcliffe Observatory, Oxford.		Banbury.	
6 ft. 0 in. 331 ft.		1 ft. 0 in. 170 ft.		1 ft. 6 in. 370 ft.		0 ft. 6 in. 266 ft.		2 ft. 0 in. 240 ft.		0 ft. 8 in. 210 ft.		7 ft. 0 in. 345 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
4·39	3·23	3·74	3·61	4·05	3·95	2·60	2·63	2·98	2·58	3·12	3·77	2·75	4·31
·80	2·96	·95	2·69	1·83	2·59	1·30	2·11	1·49	2·02	1·65	2·17	2·13	2·20
2·33	1·15	2·05	1·22	1·98	1·76	1·77	1·79	1·52	1·46	1·50	1·30	1·90	1·54
2·42	1·30	1·65	1·66	2·36	1·94	1·42	2·20	1·65	1·74	1·54	1·16	1·58	1·33
·93	4·35	·68	3·32	·82	2·86	·54	3·60	·57	3·31	·59	2·95	·88	4·47
·48	1·28	·79	1·78	·71	1·33	·52	1·12	·42	1·19	·93	1·40	·46	1·64
2·34	·99	1·75	·68	·56	·53	·20	·59	·24	·60	1·87	1·06	·49	·35
3·09	1·10	3·61	1·65	5·02	1·68	4·89	·95	4·81	·87	3·34	1·31	3·64	·91
2·58	3·36	4·44	3·30	4·50	4·56	2·47	2·76	2·77	3·12	3·99	4·41	3·05	3·87
2·52	2·20	2·74	2·57	3·02	1·33	2·23	·95	2·89	1·07	2·24	1·10	2·36	1·24
1·74	2·06	1·27	2·89	1·52	2·74	1·17	2·17	1·10	2·32	1·18	2·41	2·07	2·34
6·29	3·24	4·12	3·47	5·72	3·84	3·51	3·69	3·97	3·27	4·12	3·43	5·34	4·29
29·91	27·22	27·79	28·84	32·09	29·11	22·62	24·56	24·41	23·55	26·07	26·47	26·65	28·49

Division IV.—Eastern Counties.

Essex.										Suffolk.			
Epping.		Dorward's Hall, Witham.		Dunmow.		Bocking, Braintree.		Ashdon Rectory, Linton.		Grundisburgh.		Culford, Bury St. Edmund's.	
6 ft. 0 in. 370 ft.?		1 ft. 6 in. ? 20 ft.		0 ft. 3 in. 234 ft.		3 ft. 0 in. 200 ft.		1 ft. 0 in. 300 ft.		4 ft. 1 in.		1 ft. 6 in.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1·74	1·85	2·34	1·95	1·09	2·91	2·00	2·40	2·19	2·41	2·31	1·66	2·69	2·08
·96	1·93	·57	2·45	1·33	2·80	1·27	3·03	1·36	2·08	1·41	2·85	1·65	2·49
·91	·97	1·38	1·44	1·34	1·80	1·34	2·05	1·69	1·31	1·48	2·40	2·05	1·87
·85	1·30	·96	1·28	1·25	1·49	1·36	1·18	1·35	1·77	1·48	·66	1·68	1·23
1·04	2·55	1·18	2·78	1·85	3·20	1·61	3·17	1·25	3·21	1·01	2·58	·56	3·23
·15	1·15	·49	·91	·74	1·07	·54	1·06	·28	·90	·44	1·14	1·12	1·71
·40	·85	·12	·16	·26	·79	·73	·54	·33	·69	·31	·37	·22	·46
2·39	1·27	1·07	·97	3·31	1·83	2·49	1·58	2·02	1·85	1·60	1·20	1·98	2·25
1·89	3·80	1·22	2·90	1·90	2·34	1·64	4·68	1·83	3·85	1·41	2·93	1·74	3·58
2·40	1·05	1·70	1·90	2·14	1·88	2·01	2·18	2·28	1·62	1·90	2·08	2·62	2·78
1·08	2·20	·54	2·40	1·08	2·49	1·14	2·36	1·08	2·70	1·31	2·50	1·37	2·48
4·36	2·45	3·80	2·76	4·50	3·26	3·54	3·49	3·74	3·62	3·49	3·74	4·04	4·84
18·67	21·37	15·37	21·90	20·79	25·86	19·67	27·72	19·40	26·01	18·15	24·11	21·72	29·00

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	Division IV.—Eastern Counties (*continued*).								Division V.—South-Western Counties.			
	Norfolk.								Wiltshire.			
Height of Rain-gauge above	Geldeston, Beccles.		Cossey, Norwich.		Egmere, Fakenham.		Holkham.		Baverstock.		Marlborough.	
Ground ...... Sea-level......	1 ft. 4 in. 34 ft.		1 ft. 0 in.		4 ft. 0 in. 150 ft.		0 ft. 0 in. 39 ft.		3 ft. 0 in. 229 ft.		4 ft. 0 in. 500 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	1·83	1·51	2·12	1·68	1·92	1·57	2·00	1·98	3·45	4·40	4·43	3·50
February ...	1·28	2·47	1·49	2·38	1·86	2·03	1·60	1·92	1·13	2·70	2·15	2·59
March	1·62	3·38	2·06	3·10	2·53	1·54	1·92	2·35	1·85	1·15	1·75	1·68
April	1·70	·62	1·90	1·26	3·12	1·03	2·45	1·08	2·75	·75	2·50	1·41
May	·86	2·16	·79	2·81	·33	2·49	·25	3·00	1·30	3·80	1·38	4·17
June	·55	1·19	·70	1·69	·41	1·32	·25	1·17	·40	1·15	1·46	1·31
July	·25	2·11	·55	·58	·14	·54	·17	1·18	·65	·45	1·01	·56
August	1·69	1·68	2·82	1·66	3·37	1·92	3·36	1·55	5·60	·75	4·88	1·79
September ...	1·65	2·42	2·27	3·07	3·16	3·50	2·38	3·17	5·15	4·85	5·27	5·27
October	1·88	3·36	2·61	2·90	2·29	2·58	2·67	2·33	2·63	2·05	2·66	1·93
November ...	1·98	2·37	2·24	2·62	2·10	2·01	1·65	1·90	2·05	2·00	1·58	2·55
December ...	3·91	4·36	4·48	4·48	5·40	4·59	4·72	4·00	6·35	3·23	5·51	3·67
Totals	19·20	27·63	24·03	28·23	27·63	25·12	23·42	25·63	33·31	27·28	33·58	30·43

	Division V.—South Western Counties (*continued*).											
	Devon (*continued*).											
Height of Rain-gauge above	Landscore, Teignmouth.		Broadhembury, Honiton.		Cove, Tiverton.		Castle Hill, S. Molton.		Great Torrington.		Barnstaple.	
Ground ...... Sea-level......	0 ft. 6 in. 120 ft.		1 ft. 6 in. 400 ft.		0 ft. 10 in. 450 ft.		3 ft. 0 in. 200 ft.		1 ft. 1 in. 321 ft.		0 ft. 6 in. 31 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	4·16	2·78	3·19	3·76	5·51	5·07	6·50	5·48	6·80	5·60	6·10	4·69
February ...	·89	2·19	1·85	2·72	3·50	3·96	2·31	5·57	2·89	5·12	2·23	4·35
March	1·67	2·45	2·01	2·22	3·35	2·54	3·91	2·99	4·00	1·95	3·23	1·06
April	2·32	·74	2·08	1·11	3·54	1·86	2·98	2·71	3·00	1·68	2·50	1·89
May	1·56	6·57	1·15	5·36	1·31	5·48	1·86	6·17	1·98	4·56	1·91	4·90
June	·42	·73	1·22	·53	·85	·41	·31	·50	·34	·32	·52	·54
July	·43	·31	1·00	·84	·59	·77	·78	·93	·42	·86	·38	·90
August	3·57	·28	5·50	·66	5·42	1·03	5·51	2·28	5·24	·75	4·68	1·43
September ...	4·04	2·37	5·23	4·25	3·38	5·94	3·80	7·09	3·27	7·27	3·73	6·00
October	1·55	1·92	3·24	1·73	3·95	2·60	6·43	4·85	5·49	3·31	5·59	4·76
November ...	3·46	1·18	3·14	2·39	2·37	4·91	2·77	4·62	3·18	4·54	2·29	4·01
December ...	7·38	4·04	6·27	4·41	9·72	5·72	8·85	5·24	8·05	6·43	6·78	5·19
Totals	31·45	25·56	35·88	29·98	43·49	40·29	46·01	48·43	44·66	42·39	39·94	39·72

ENGLAND.

Division V.—South-Western Counties (*continued*).

Wiltshire (*continued*).		Dorset.						Devon.					
Chippenham, West Tytherton.		Blandford.		Dorchester.		Bridport.		Saltram Gardens, Plymouth.		Ivybridge.		Dartmoor Prison Reservoir.	
1 ft. 2 in. 150 ft.		1 ft. 0 in.		0 ft. 6 in. 250 ft.		0 ft. 11 in. 85 ft.		0 ft. 6 in. 96 ft.		3 ft. 0 in. 175 ft.		0 ft. 2 in. 1400 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·38	3·46	5·57	5·01	4·15	4·71	3·76	4·59	5·18	5·97	5·57	6·94	9·01	9·74
1·41	2·58	2·16	3·33	2·15	3·48	1·91	3·07	2·50	3·21	2·34	5·67	5·08	9·79
1·42	1·22	2·56	2·56	1·69	2·21	1·39	2·25	2·34	2·29	3·78	3·41	6·68	4·51
2·51	1·08	2·58	1·27	3·41	1·21	2·00	1·11	4·24	1·45	4·54	3·06	7·04	3·25
1·13	4·15	1·67	5·61	2·06	5·19	1·61	4·74	2·15	7·20	3·43	6·86	3·71	9·61
·31	1·34	·60	1·25	·93	1·21	·40	1·14	·76	·40	·76	·37	2·02	·82
·80	·79	·51	·39	·86	·68	·48	·41	·72	1·13	·41	·88	1·24	3·48
4·22	1·12	4·80	·92	6·15	·86	4·61	·25	5·00	·51	5·60	·76	6·86	2·35
3·74	3·85	5·39	5·30	5·69	5·45	3·40	3·92	5·63	3·23	4·69	6·76	7·52	10·53
2·28	1·69	3·78	1·77	3·60	2·45	3·32	2·03	5·38	2·99	5·70	2·61	8·83	5·30
1·42	2·37	2·91	1·98	3·47	2·53	2·83	2·09	4·70	3·21	5·22	4·00	6·19	8·13
4·31	3·32	7·11	4·67	8·15	4·40	6·88	4·37	9·90	4·71	9·22	5·26	13·47	7·49
26·93	26·97	39·64	34·06	42·31	34·38	32·59	29·97	48·50	36·30	51·26	46·58	77·65	75·00

Division V.—South-Western Counties (*continued*.)

Cornwall.													
Helston.		Penzance.		Tehidy Park, Redruth.		Truro.		Bodmin.		Treharrock House, Wadebridge.		Altarnum.	
5 ft. 0 in. 115 ft.		2 ft. 6 in. 94 ft.		0 ft. 6 in. 100 ft.		40 ft. 0 in. 56 ft.		2 ft. 6 in. 338 ft.		3 ft. 6 in. 300 ft.		0 ft. 10 in. 570 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
4·07	3·56	6·92	6·93	7·25	6·85	7·15	6·84	6·48	7·02	4·01	4·67	9·18	9·23
2·25	3·33	2·62	3·98	2·70	4·40	2·42	3·88	2·37	4·56	1·96	4·26	4·48	6·93
2·05	2·33	2·25	2·82	2·55	2·30	2·48	2·46	3·38	2·76	2·34	2·13	4·80	2·65
2·77	1·22	2·97	1·42	2·50	1·50	3·61	·97	3·85	1·49	2·27	1·04	5·13	2·12
1·40	4·09	1·68	4·15	1·70	2·40	1·69	5·42	2·75	6·28	1·10	5·12	3·29	7·45
·94	·55	·66	·50	·90	·70	·54	·26	·82	·54	·48	·96	1·45	1·06
·89	·43	·86	·65	1·00	·80	1·04	·35	·81	·95	·98	·71	1·21	·60
3·32	·77	3·83	·80	3·50	·60	2·99	·48	4·00	·76	4·02	·78	5·75	2·28
3·51	4·72	2·55	4·83	4·10	4·40	4·03	4·46	6·19	5·76	2·59	5·12	6·57	8·89
4·71	2·65	5·40	2·35	4·70	2·75	5·00	2·27	6·00	3·61	5·36	3·17	8·67	4·73
3·90	4·64	3·99	4·90	5·30	4·11	5·81	4·81	7·80	4·19	4·16	4·04	7·37	6·61
6·75	4·31	6·48	5·69	7·05	6·05	8·26	5·62	9·40	5·52	6·86	4·29	13·23	7·97
36·56	32·60	40·21	39·02	43·25	36·86	45·02	37·82	53·85	43·44	36·13	36·29	71·13	60·52

ENGLAND.

Division V.—South-Western Counties (continued).									Division VI.—West Midland Counties.			
	Somerset.								Gloucester.			
	Fulland's School, Taunton.		Long Sutton, Langport.		Sherborne Reservoir, East Harptree.		Batheaston Reservoir.		Clifton.		Cirencester.	
Height of Rain-gauge above Ground …… Sea-level……	1 ft. 4 in. …………		0 ft. 7 in. 50 ft.		1 ft. 0 in. 336 ft.		2 ft. 0 in. 226 ft.		0 ft. 6 in. 192 ft.		1 ft. 2 in. 446 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ……	3·78	3·20	3·30	3·98	7·53	7·44	4·46	4·38	5·90	5·37	4·68	5·60
February ..	·82	2·94	1·34	2·38	1·78	5·73	1·58	2·86	1·97	3·88	2·03	3·37
March ……	2·77	1·28	1·72	1·62	4·04	1·85	1·50	1·46	1·79	1·20	2·56	1·60
April ………	1·77	·51	1·32	·88	3·59	1·78	2·12	1·00	2·31	1·13	2·20	1·42
May ………	·95	4·63	·93	5·41	1·47	7·14	1·10	4·55	1·77	6·30	1·71	4·09
June ………	·61	·91	1·01	·95	1·73	1·28	·92	1·35	·64	1·03	·31	1·52
July ………	1·26	·44	1·21	·46	1·62	1·74	·86	1·00	·88	·96	·71	·72
August ……	5·65	·24	4·96	·78	6·51	1·98	3·90	·74	5·76	1·40	4·02	1·51
September …	3·58	3·27	3·48	3·94	3·81	6·72	3·64	4·45	2·99	5·77	2·89	6·55
October ……	2·72	2·90	2·38	2·14	6·25	3·00	2·72	1·50	2·76	2·44	2·64	2·00
November …	1·34	1·56	1·57	1·58	2·74	4·20	1·75	2·04	1·67	2·40	2·23	2·85
December …	5·23	3·13	5·01	3·34	10·06	6·55	5·62	3·93	5·67	4·29	6·70	5·30
Totals ……	30·48	25·01	28·23	27·46	51·13	49·41	30·17	29·26	34·11	36·17	32·68	36·53

Division VI.—West Midland Counties (cond.).							Division VII.—North Midland Counties.					
	Worcester (continued).		Warwick.				Leicester.					
	Orleton, Tenbury.		Arden House, Henley-in-Arden.		Birmingham.		Wigston, Leicester.		Thornton.		Belvoir Castle.	
Height of Rain gauge above Ground …… Sea-level……	0 ft. 9 in. 200 ft.		2 ft. 0 in. 400 ft.		0 ft. 10 in. 340 ft.		0 ft. 6 in. 220 ft.		2 ft. 8 in. ? 420 ft.		1 ft. 0 in. 237 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ……	3·07	4·53	2·28	3·49	2·29	3·46	1·71	2·82	1·78	2·41	1·88	2·93
February …	2·21	2·90	1·83	1·87	1·89	3·08	1·64	1·91	1·96	2·18	1·54	2·55
March ……	1·76	1·79	1·98	2·14	2·92	2·50	2·56	1·96	2·09	1·87	1·90	2·75
April ………	1·80	1·47	1·67	1·06	1·94	1·82	1·27	2·65	1·36	1·45	1·69	2·47
May ………	2·38	5·51	1·06	4·63	1·67	5·75	·53	4·72	1·08	6·15	·51	4·74
June ………	·45	1·02	·30	·73	·19	1·21	·33	1·71	·27	1·17	·49	1·50
July ………	·90	1·00	·20	·87	·39	·58	·00	1·13	·05	·59	·10	·78
August ……	4·60	1·20	4·87	·89	5·52	1·26	4·00	1·21	3·73	1·90	2·94	1·52
September …	2·99	5·51	2·51	3·18	2·47	4·10	2·61	2·43	2·18	3·52	2·82	2·95
October ……	2·24	2·06	1·95	1·24	1·92	1·66	2·28	·75	2·52	·98	2·90	1·10
November …	1·90	2·37	1·72	2·12	1·82	2·04	1·36	1·83	1·29	2·04	1·33	1·95
December …	6·65	4·45	5·66	3·45	6·60	4·00	4·95	3·58	5·19	3·81	6·07	3·77
Totals ……	30·95	33·81	26·03	25·67	29·62	31·46	23·24	26·70	23·50	28·07	24·17	29·01

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Division VI.—West Midland Counties (*continued*).

Gloucester (*continued*).		Hereford.		Shropshire.				Worcester.					
Quedgeley.		Stretton Rectory, Hereford.		Haughton Hall, Shifnall.		Hengoed, Oswestry.		Northwick Park.		West Malvern.		Lark Hill, Worcester.	
0 ft. 10 in. 50 ft.		1 ft. 0 in. 190 ft.		4 ft. 6 in. 350 ft.		6 ft. 0 in. 471 ft.		1 ft. 6 in.		1 ft. 3 in. 900 ft.		1 ft. 0 in. 157 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·46	5·50	2·85	4·99	1·84	2·91	4·56	4·86	2·88	5·24	2·60	5·39	2·54	4·65
1·77	3·67	1·51	3·04	2·17	2·00	2·13	3·00	2·18	2·22	1·56	3·28	1·52	2·70
1·82	1·58	1·65	1·53	1·36	1·59	2·89	1·69	1·58	1·89	1·27	1·30	1·59	1·37
1·56	1·05	1·88	·91	1·51	1·78	2·30	1·44	1·68	1·93	2·21	1·82	2·28	1·26
2·29	3·12	1·70	4·46	1·52	4·73	2·27	6·45	1·16	3·64	2·15	5·51	1·79	5·11
·26	1·42	·34	·59	·14	·96	·38	·94	·00	1·42	·36	1·16	·41	1·23
·58	·94	1·30	·46	·45	·72	·66	1·28	1·04	·08	1·07	·53	1·09	·30
3·22	1·09	4·85	·85	3·18	1·41	2·71	1·40	1·55	·30	5·47	1·14	4·26	1·34
2·51	6·20	3·65	4·28	2·62	4·76	2·78	5·92	1·96	3·17	2·50	3·21	2·67	5·33
1·85	1·92	1·63	3·19	1·50	1·59	3·22	2·63	3·39	3·37	2·68	3·96	1·93	1·31
2·74	2·05	1·28	2·47	1·14	2·21	2·52	3·22	2·30	2·47	2·07	1·83	1·94	2·21
5·07	5·15	6·34	3·71	5·52	3·31	10·69	5·18	4·24	4·99	6·11	4·55	5·78	3·74
7·13	33·69	28·98	30·48	22·95	27·97	37·11	38·01	23·96	30·72	30·05	33·68	27·80	30·55

Division VII.—North Midland Counties (*continued*).

Lincoln.												Nottingham.	
Lincoln.		Market Rasen.		Gainsborough.		Brigg.		Grimsby.		New Holland.		Welbeck.	
3 ft. 6 in. 26 ft.		3 ft. 6 in. 100 ft.		3 ft. 6 in. 76 ft.		3 ft. 6 in. 16 ft.		15 ft. 0 in. 42 ft.		3 ft. 6 in. 18 ft.		3 ft. 0 in. 80 ft.	
868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
n.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1·39	2·34	2·37	2·89	1·01	1·84	1·34	2·20	1·34	2·49	1·60	2·42	1·54	2·32
1·59	1·65	1·73	2·01	1·12	·91	1·45	·94	1·53	1·52	1·66	1·40	1·92	1·51
1·30	2·61	·94	2·91	·65	1·12	1·02	1·33	1·97	2·10	1·75	1·64	1·11	2·23
·96	2·15	1·68	1·57	·94	2·02	1·76	1·44	2·29	1·66	2·27	1·70	1·31	1·25
·23	4·36	·20	3·76	·94	4·38	·69	3·55	·22	4·73	·47	4·48	1·20	6·28
·49	1·25	·30	1·76	·55	1·86	·46	1·45	·79	1·18	·89	·95	·23	·38
·41	·49	·24	·63	·21	·22	·44	·60	·72	·34	·84	·17	·19	·03
·37	1·24	2·52	2·15	5·23	2·68	3·44	2·21	3·56	1·91	3·08	1·83	3·40	1·90
·92	3·30	2·22	2·35	2·83	3·12	2·27	3·57	1·86	3·15	1·74	2·55	2·22	4·36
·21	·68	1·80	1·42	1·78	1·31	2·32	1·65	2·59	1·92	2·55	1·39	2·49	1·26
·94	1·13	2·09	1·65	·75	1·30	1·85	1·13	1·10	1·70	1·78	1·51	·92	1·61
·83	2·90	5·26	2·78	5·10	4·49	5·03	4·70	5·56	3·30	5·99	3·27	6·13	3·37
·64	24·10	21·35	25·88	21·11	25·25	22·07	24·77	23·53	26·00	24·62	23·31	22·66	26·50

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Division VII.—North Midland Counties (continued).									Div. VIII.—North-Western Counties.			
	Derby.								Cheshire.			
Height of Rain-gauge above	Derby.		Chesterfield.		Comb's Moss.		Chapel-en-le-Frith.		Macclesfield.		Cholmondelly Castle, Nantwich.	
Ground ...... Sea-level......	5 ft. 0 in. 180 ft.		3 ft. 6 in. 248 ft.		3 ft. 6 in. 1669 ft.		3 ft. 6 in. 963 ft.		3 ft. 6 in. 539 ft.		1 ft. 6 in. 42 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	1·81	2·96	1·69	3·36	4·90	7·68	2·36	4·19	1·94	2·70	2·37	2·89
February ...	2·58	1·89	1·72	2·01	3·30	3·61	3·66	4·45	2·02	4·12	2·03	1·89
March	2·32	1·64	2·48	2·24	6·35	·71	5·65	·92	3·83	1·27	2·12	1·57
April	1·55	1·48	1·93	1·83	5·93	3·14	3·17	2·37	2·74	2·34	1·95	1·54
May	1·35	3·97	1·05	5·36	1·46	5·10	1·54	3·47	1·93	4·79	1·49	5·84
June	·27	1·41	·55	·75	·68	2·12	·50	1·81	·17	·97	·55	1·01
July	·33	·65	·00	·05	·22	·81	·34	·74	·39	1·17	·58	1·67
August	3·14	·99	2·28	·88	3·49	3·18	3·95	3·06	3·42	3·22	3·53	2·33
September ...	1·72	5·31	2·46	4·02	3·45	7·55	2·63	7·15	1·94	8·20	2·66	6·36
October	3·01	1·10	2·80	1·41	5·53	3·79	5·61	3·53	4·60	2·54	2·68	2·70
November ...	1·06	2·04	1·04	1·72	2·92	6·31	2·53	4·94	1·64	3·63	2·61	3·30
December ...	6·88	3·91	7·47	3·90	8·90	5·50	9·20	6·19	7·89	4·74	6·93	3·13
Totals	26·02	27·35	25·47	27·53	47·13	49·50	41·14	42·82	32·51	39·69	29·50	34·23

Division VIII.—North-Western Counties (continued).					Division IX.—Yorkshire.							
	Lancashire (continued).				York.—West Riding.							
Height of Rain-gauge above	Caton, Lancaster.		Holker, Cartmel.		Broomhall Park, Sheffield.		Redmires, Sheffield,		Tickhill.		Penistone.	
Ground ...... Sea-level......	1 ft. 9 in. 120 ft.		4 ft. 8 in. 155 ft.		2 ft. 0 in. 337 ft.		4 ft. 0 in. 1100 ft.		2 ft. 0 in. 61 ft.		3 ft. 6 in. 717 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	3·38	4·49	2·91	5·06	2·47	3·15	1·78	3·62	2·24	2·49	3·11	2·96
February ...	3·12	5·99	3·65	6·13	1·88	2·67	3·98	4·26	1·45	1·78	1·97	3·48
March	5·02	1·28	5·11	1·22	2·64	1·98	4·74	2·53	1·14	2·01	3·36	1·76
April	2·61	2·93	2·74	2·64	2·17	1·82	2·70	2·64	1·40	1·71	1·94	1·92
May	2·31	3·03	2·17	3·40	·94	5·76	1·48	6·68	1·03	5·07	·63	5·62
June	·45	2·65	·67	2·01	·47	·87	·59	1·29	·36	·97	·24	1·07
July	·64	·96	·53	1·31	·09	·24	·17	·67	·41	·27	·45	·53
August	4·98	2·53	6·03	2·38	2·67	1·08	3·15	2·07	1·88	1·39	2·18	1·54
September ...	2·19	8·21	2·94	8·86	3·32	4·95	3·90	6·14	2·46	3·12	3·63	5·34
October	5·46	3·51	5·04	3·57	3·37	1·45	3·87	2·76	2·62	1·75	3·30	2·05
November ...	2·60	4·63	3·51	6·25	1·99	2·17	3·18	4·93	1·05	1·59	2·32	2·67
December ...	9·54	4·69	10·28	5·40	9·03	4·65	9·49	6·31	6·60	3·23	8·22	5·09
Totals	42·30	44·90	45·58	48·23	31·04	30·79	39·07	43·90	22·64	25·38	31·35	34·03

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Division VIII.—North-Western Counties (*continued*).

Lancashire.

Manchester.		Waterhouses.		Bolton-le-Moors.		Rufford, Ormskirk.		Howick House, Preston.		South Shore, Blackpool.		Stonyhurst*.	
2 ft. 7 in. 106 ft.		3 ft. 6 in. 345 ft.		3 ft. 6 in. 286 ft.		0 ft. 8 in. 38 ft.		0 ft. 6 in. 72 ft.		1 ft. 8 in. 29 ft.		1 ft. 3 in. 381 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
2·75	2·69	2·82	2·57	3·38	3·26	2·43	3·55	2·80	4·00	2·60	3·40	4·45	3·80
2·11	4·44	2·56	4·36	2·89	5·51	2·06	3·93	2·25	4·75	2·05	4·40	4·35	4·40
4·00	1·27	5·30	1·24	6·34	1·68	3·50	1·13	3·70	1·20	3·57	1·12	1·45	6·40
1·68	2·10	1·70	1·91	2·33	3·12	1·66	2·84	1·90	2·80	1·85	1·90	5·93	2·30
·87	2·73	1·14	2·99	1·15	2·98	1·68	3·40	1·65	3·90	2·05	2·78	2·10	1·60
·37	1·12	·47	1·25	·33	1·74	·41	1·43	·55	1·70	·30	1·00	2·14	·70
·45	1·13	·29	1·02	·60	1·24	·31	·98	·35	1·20	·22	·50	5·43	·70
2·50	2·63	2·74	2·79	5·29	4·21	3·24	1·97	3·40	1·95	3·45	1·42	3·51	4·50
1·76	6·32	1·54	6·66	2·34	9·21	1·58	6·71	1·20	7·20	1·35	5·90	4·94	2·50
4·51	3·12	5·00	2·43	8·00	5·07	5·56	3·30	6·30	3·10	4·50	3·20	5·36	6·80
3·11	4·28	2·81	4·63	3·87	6·70	2·88	3·87	2·70	4·10	3·00	3·80	2·16	4·00
8·12	3·62	7·94	5·01	9·82	4·28	6·88	2·82	8·42	5·10	8·16	2·87	5·22	9·50
32·23	35·45	34·31	36·86	46·34	49·00	32·19	35·93	35·22	41·00	33·10	32·29	47·04	47·20

Division IX.—Yorkshire (*continued*).

York.—West Riding (*continued*).

Saddleworth.		Longwood, Huddersfield.		Ackworth, Pontefract.		Well Head, Halifax.		Ovenden Moor, Halifax.		Eccup, Leeds.		York.	
5 ft. 0 in. 640 ft.		4 ft. 6 in. 600 ft.		0 ft. 3 in. 135 ft.		0 ft. 11 in. 487 ft.		0 ft. 10 in. 1375 ft.		0 ft. 0 in. 340 ft.		0 ft. 6 in. 50 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·66	2·59	4·14	2·90	2·45	2·40	2·57	2·81	4·40	4·00	2·94	2·94	1·45	2·81
4·35	6·36	2·99	6·00	·77	1·15	4·34	5·72	3·30	6·10	1·70	2·69	1·33	1·78
4·09	1·09	3·98	1·23	1·27	1·40	4·30	2·50	4·20	2·10	2·78	1·56	1·52	1·89
1·20	1·93	1·61	1·89	1·77	1·90	1·20	1·65	2·00	2·20	1·70	1·90	1·82	2·18
2·85	5·71	·84	5·64	·77	5·47	·77	5·64	1·30	5·50	1·21	5·69	1·28	4·49
·63	1·21	·28	·66	1·40	·99	·07	·76	·10	1·10	·22	·73	1·26	1·05
·86	1·53	·36	·80	·24	·86	·40	·55	·20	·30	·30	·57	·40	1·31
3·64	3·47	2·29	1·90	2·13	1·20	2·70	2·00	4·10	1·70	2·12	1·57	2·56	1·70
2·40	7·65	3·63	5·40	3·98	3·45	3·32	5·60	5·00	7·50	3·65	4·70	3·24	3·83
5·92	3·46	3·67	2·19	2·13	1·07	3·61	1·88	5·00	2·70	2·85	1·32	2·89	1·58
1·84	5·02	2·91	3·81	1·01	1·94	2·62	3·92	2·80	4·50	2·34	2·06	2·00	1·65
9·77	5·06	8·20	4·46	5·78	2·85	8·67	4·83	9·90	7·00	6·99	4·39	5·95	3·65
41·21	45·08	34·90	36·88	23·70	24·68	34·57	37·86	42·30	44·70	28·80	30·12	25·70	27·92

* Corrected for instrumental error.

ENGLAND.

Division IX.—Yorkshire (*continued*).

Height of Rain-gauge above	York.—West Riding (*continued*).						York—East Riding.				York—North Riding.	
	Harrogate.		Settle.		Arncliffe, Skipton.		Beverley Road, Hull.		Holme, on Spalding Moor.		Malton.	
Ground ...... Sea-level......	0 ft. 6 in. 420 ft.		40 ft. 0 in. 498 ft.		3 ft. 0 in. 750 ft.		3 ft. 10 in. 11 ft.		3 ft. 0 in. 30 ft.		1 ft. 0 in. 73 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	3·28	2·50	4·37	5·03	8·03	7·89	2·24	2·66	1·57	1·99	2·21	3·03
February ...	1·49	3·21	4·45	7·72	4·82	9·08	1·53	1·40	1·14	1·23	1·12	1·99
March	2·79	1·94	4·21	1·85	8·19	2·17	1·97	2·29	1·28	1·66	1·84	2·25
April	2·18	1·62	3·10	2·62	3·83	3·95	2·10	1·94	1·73	1·78	1·66	1·77
May	1·93	5·13	1·56	3·44	2·63	4·11	·70	4·69	1·17	4·29	1·59	3·97
June	·36	1·21	·20	0·00	1·40	1·96	1·07	1·25	·63	1·38	·88	1·51
July	·62	·28	·35	·97	·81	1·59	·85	·25	·63	·59	·92	1·07
August	3·11	1·24	4·74	2·05	6·52	2·48	3·47	2·24	1·78	2·17	2·16	1·23
September ...	3·39	3·64	2·82	6·92	4·28	11·64	1·72	2·90	2·41	2·48	2·81	3·26
October	3·31	1·73	4·37	·52	7·53	3·31	2·69	1·99	2·62	1·96	2·94	2·35
November ...	2·59	2·28	3·05	4·65	6·42	8·71	1·66	2·24	1·36	1·78	1·58	2·27
December ..	7·78	4·67	8·70	5·77	12·24	8·12	6·54	4·44	5·02	3·42	6·24	3·99
Totals	32·83	29·45	41·92	41·54	66·70	65·01	26·54	28·29	21·34	24·73	25·95	28·69

Division X.—Northern Counties (*continued*).

Height of Rain-gauge above	Northumberland (*continued*).				Cumberland.							
	Park End, Hexham.		Lilburn Tower, Alnwick.		Stonethwaite, Borrowdale.		Seathwaite, Borrowdale.		Whinfell Hall, Cockermouth.		Post Office, Keswick.	
Ground ...... Sea-level......	0 ft. 4 in. 277 ft.		6 ft. 9 in. 290 ft.		0 ft. 6 in. 330 ft.		1 ft. 0 in. 422 ft.		2 ft. 0 in. 266 ft.		6 ft. 4 in. 270 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	4·08	2·80	3·02	2·13	9·42	14·57	13·54	17·43	5·90	7·15	9·95	8·95
February ...	6·02	5·60	1·20	1·23	17·52	19·81	19·90	23·13	6·42	8·46	7·46	12·73
March	3·40	1·15	1·13	1·81	18·29	1·56	27·24	3·21	8·79	·61	7·59	·58
April	2·75	2·12	2·85	·89	6·19	5·49	8·95	10·26	3·44	3·10	3·88	2·37
May	1·29	2·36	1·35	2·61	5·03	2·96	6·98	3·16	2·92	2·45	2·82	2·24
June	·79	1·77	·51	2·25	2·06	4·04	3·47	5·13	1·89	2·16	1·09	2·71
July	·47	·93	·58	·77	1·10	6·04	2·32	8·30	1·03	2·14	·35	2·48
August	2·52	1·27	3·61	1·43	11·72	3·29	13·70	4·51	6·02	2·28	7·14	2·24
September ...	3·60	4·85	3·76	3·72	4·47	20·03	5·77	24·09	2·39	10·60	3·21	13·23
October	2·43	1·91	1·56	2·03	14·37	6·04	18·30	9·95	7·76	4·75	5·43	3·94
November ...	2·29	4·34	3·33	2·11	7·64	18·03	9·43	23·19	3·24	7·71	2·72	11·26
December ...	4·69	4·33	4·54	2·99	21·68	12·86	27·51	17·75	9·83	7·40	14·08	9·27
Totals	34·33	33·43	27·44	23·97	119·49	114·72	157·11	150·11	59·63	58·81	65·72	72·00

ENGLAND.

Division IX.—Yorkshire (continued).				Division X.—Northern Counties.									
York—North Riding (continued).				Durham.				Northumberland.					
Beadlam Grange.		Scarborough.		Darlington.		Sunderland.		Allenheads.		Bywell.		North Shields.	
0 ft. 6 in. 192 ft.		1 ft. 0 in. 100 ft.		4 ft. 0 in. 140 ft.		1 ft. 6 in. 85 ft.		0 ft. 5 in. 1360 ft.		0 ft. 6 in. 87 ft.		1 ft. 0 in. 124 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
2·26	3·24	1·75	2·34	4·58	2·46	1·77	1·98	8·63	6·06	4·18	2·38	2·04	2·28
·42	2·28	1·30	1·44	1·33	·78	·70	1·11	4·68	9·26	1·59	1·80	1·82	1·32
2·32	2·42	1·16	2·33	1·44	1·71	1·12	1·97	5·85	2·09	2·08	1·65	1·14	1·30
1·76	1·66	2·01	1·84	2·19	1·16	2·23	1·47	3·93	2·43	3·24	1·74	3·04	1·76
1·95	3·15	1·10	3·21	1·62	3·28	1·23	2·86	1·66	4·66	·94	3·61	1·04	2·57
·55	1·87	·40	1·09	·46	1·32	·46	1·27	·42	1·67	·19	1·42	·43	1·27
·61	1·06	·78	·91	2·00	1·01	1·01	1·09	·61	·87	·91	·25	·49	·77
2·60	1·16	2·50	1·57	3·13	1·43	2·02	1·58	5·72	1·77	2·07	1·23	1·38	1·29
2·04	3·26	2·72	3·76	5·47	3·76	4·20	3·68	5·59	8·97	3·90	3·49	3·58	2·81
3·28	3·27	3·10	3·81	2·61	2·45	2·11	3·01	4·05	3·08	1·56	1·81	2·07	2·81
·90	2·07	2·14	2·84	2·11	2·26	2·52	2·18	5·03	7·64	2·72	2·53	2·23	2·95
7·02	3·77	4·94	4·59	10·31	2·41	4·13	3·16	10·25	5·94	4·33	3·06	3·59	2·81
25·71	29·21	23·90	29·73	37·25	24·03	23·50	25·36	56·42	54·44	27·71	24·97	23·35	23·94

Division X.—Northern Counties (continued).													
Cumberland (continued.)								Westmoreland.					
'ockermouth.		Mire House, Bassenthwaite.		Edenhall, Penrith.		Scaleby, Carlisle.		Kendal.		The How, Troutbeck.		Appleby.	
0 ft. 6 in. 158 ft.		0 ft. 7 in. 310 ft.		1 ft. 0 in. 32 ft.?		0 ft. 8 in. 120 ft.		4 ft. 6 in. 149 ft.		1 ft. 2 in. 470 ft.		1 ft. 0 in. 442 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
5·15	5·35	5·32	6·53	4·20	4·80	1·56	3·28	4·09	5·34	6·91	9·83	6·01	5·51
6·52	6·63	6·85	8·12	3·00	4·10	3·35	5·04	6·67	8·40	11·79	14·14	3·57	5·34
6·92	·85	8·19	·74	4·00	·50	3·04	·79	7·06	1·42	12·20	2·16	4·23	·66
3·07	2·69	3·10	2·53	2·90	1·20	2·57	2·34	3·08	3·98	4·17	4·63	2·36	1·18
3·22	2·05	3·15	3·26	1·50	2·00	2·30	2·08	2·06	2·73	2·41	3·08	1·41	1·54
1·28	1·66	1·15	2·09	1·00	1·50	·84	1·40	·81	1·75	1·09	2·52	·68	1·28
·80	1·81	·61	1·38	·85	1·50	·71	2·16	·56	1·61	·75	2·66	·58	·96
4·11	1·80	5·31	2·20	3·60	1·00	4·17	1·13	6·16	1·88	7·49	2·79	2·47	1·93
1·93	7·55	3·13	9·55	2·95	6·20	2·60	5·95	2·69	10·97	3·51	14·45	2·74	7·54
5·99	3·97	6·50	3·94	3·00	3·90	2·87	1·85	6·00	3·59	10·64	4·41	3·02	2·48
2·91	6·17	4·10	7·94	2·15	1·50	1·41	4·86	3·14	6·99	6·15	10·45	3·07	3·41
8·22	5·78	10·97	7·33	6·03	2·30	4·35	4·32	10·43	6·84	15·66	10·95	8·90	5·66
0·12	46·31	58·38	55·61	35·18	30·50	29·77	35·20	52·75	55·50	82·77	82·07	39·04	37·49

WALES.

Division XI.—Monmouth, Wales, and the Islands.

Height of Rain-gauge above	Monmouth.				Glamorgan.		Carmarthen.		Pembroke.			
	Llanfrechfa, Newport		Abergavenny.		Swansea.		Carmarthen.		Haverford-west.		Kilgerran.	
Ground ...... Sea-level......	1 ft. 0 in. 360 ft.		1 ft. 3 in. 220 ft.		16 ft. 0 in. 30 ft.		0 ft. 5 in. 78 ft.		2 ft. 5 in. 60 ft.		1 ft. 2 in. 80 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ...	7·45	7·89	3·55	8·72	2·66	4·62	3·53	6·83	5·72	9·05	4·22	7·78
February ...	2·61	5·47	1·70	3·89	1·56	5·21	2·16	4·72	2·22	6·11	2·54	5·84
March	3·17	1·94	2·60	2·18	2·29	1·53	3·05	2·88	3·03	3·14	3·86	1·33
April	3·41	1·50	2·87	1·31	1·47	2·03	1·89	3·03	2·02	2·99	2·09	2·72
May	2·16	5·70	2·09	5·23	2·58	3·20	2·22	3·99	2·35	5·65	1·82	3·68
June	·62	·84	·35	·75	·08	·49	·80	·94	1·16	·58	·96	·42
July	·23	1·33	·41	·43	·35	1·06	1·10	2·00	1·09	2·38	1·81	·88
August	5·22	1·64	4·91	·70	4·11	1·24	2·08	1·91	3·48	2·20	3·50	·97
September ...	5·00	7·38	5·64	5·80	2·42	5·85	4·07	7·80	4·04	8·52	3·01	7·44
October	3·15	1·71	2·24	2·25	3·64	2·73	5·19	3·52	5·50	3·73	3·47	3·50
November ...	4·78	2·57	3·07	1·90	1·50	2·24	3·40	4·28	4·74	4·40	1·04	4·06
December ...	9·73	8·52	9·58	5·35	6·86	3·99	10·60	6·96	10·48	5·94	14·89	5·49
Totals	47·53	46·49	39·01	38·51	29·52	34·19	40·09	48·86	45·83	54·69	43·21	44·11

Division XI.—Monmouth, Wales, and the Islands (*continued*).

Height of Rain-gauge above	Merioneth.		Carnarvon.				Isle of Man.				Channel Islands.	
	Brithdin, Dolgelly.		Plas Brereton, Carnarvon.		Llanfairfe-chan.		Douglas.		Point of Ayr.		Guernsey.	
Ground ...... Sea-level......	2 ft. 0 in. 500 ft.		1 ft. 0 in. 25 ft.		0 ft. 8 in. 150 ft.		0 ft. 6 in.		3 ft. 4 in. 27 ft. ?		12 ft. 0 in. 204 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ...	9·13	9·37	4·15	6·54	3·67	5·01	4·80	5·40	2·60	4·34	4·09	3·8
February ...	6·81	10·77	3·60	2·91	3·15	4·19	3·80	4·61	2·70	3·30	1·33	3·14
March	7·48	3·09	3·79	1·57	3·30	1·78	5·00	1·60	3·55	·77	1·81	2·8
April	4·44	6·45	2·10	2·36	2·32	2·34	1·90	2·32	1·69	1·78	2·92	2·21
May	3·54	3·12	1·47	3·18	1·30	3·07	2·00	2·43	2·66	2·13	2·48	4·6
June	·65	1·47	·28	1·34	·40	1·09	·10	·96	·48	·63	·43	1·24
July	1·39	1·92	1·13	·83	·83	·40	·00	·36	·10	·91	·39	·1
August	5·87	4·05	2·51	1·99	2·61	1·98	3·80	·99	4·30	1·38	3·84	·6
September ...	4·23	13·62	1·93	10·17	2·24	7·74	1·50	4·15	1·88	4·11	2·04	3·0
October	7·49	5·27	4·19	4·58	3·31	3·87	2·30	·76	1·65	1·45	4·28	2·7
November ...	5·52	8·68	3·75	3·79	3·51	3·55	1·87	3·42	2·15	4·21	2·49	3·2
December ...	15·71	9·43	8·76	4·29	8·43	3·48	7·43	4·65	7·29	2·64	8·66	5·3
Totals	72·26	77·24	37·66	43·55	35·07	38·50	34·50	31·65	31·05	27·65	34·76	32·9

WALES.

Division XI.—Monmouth, Wales, and the Islands (*continued*).

Cardigan.				Brecknock.		Radnor.		Flint.				Denbigh.	
Lampeter.		Aberystwith.		Pen-y-Maes, Hay.		Cefnfaes, Rhayader.		Hawarden.		Maes-y-dre, Holywell.		Llandudno.	
5 ft. 0 in. 420 ft.		1 ft. 0 in. 42 ft.		1 ft. 0 in. 317 ft.		2 ft. 0 in. 880 ft.		1 ft. 0 in. 268 ft.		5 ft. 0 in. 400 ft.		0 ft. 6 in. 99 ft.	
868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
6·36	7·23	5·57	5·45	3·55	5·28	5·55	5·56	2·09	3·26	1·69	2·85	3·81	4·12
3·17	4·77	2·95	4·25	1·50	3·46	3·10	5·49	2·05	2·75	1·20	3·58	3·01	3·43
4·22	2·47	4·29	1·93	2·44	1·67	4·21	1·78	2·32	2·04	1·85	1·16	3·26	1·37
2·70	2·10	2·84	3·32	1·59	1·31	2·79	2·77	1·66	1·80	·54	1·53	1·46	2·17
2·08	3·90	1·56	2·64	2·12	5·30	2·58	4·59	1·78	5·56	·67	4·88	·71	3·90
·38	·55	·52	·91	·39	·89	·24	·70	·15	·93	·04	1·03	·15	·82
5·14	·97	2·47	1·16	1·19	·78	1·19	·82	·43	·73	·22	·42	·29	·50
·83	2·23	3·33	3·47	5·43	·95	4·38	1·49	2·80	1·31	1·18	1·78	1·73	1·66
3·86	8·21	2·26	7·56	3·99	6·47	3·86	7·52	2·20	5·15	2·03	4·47	1·77	6·50
4·40	3·91	4·71	4·06	2·61	2·31	3·95	2·70	2·22	3·16	2·82	3·07	2·56	2·77
4·13	4·44	2·77	5·30	1·38	2·61	2·91	5·17	3·24	3·56	2·17	3·31	2·78	3·92
0·99	6·45	9·13	3·01	7·18	4·44	7·77	7·39	6·67	2·66	6·32	2·30	8·22	3·07
8·26	47·23	42·40	43·06	33·37	35·47	42·53	45·98	27·61	32·91	20·73	30·38	29·75	34·23

Div. XI.—Monmouth, Wales, &c. (*continued*).				SCOTLAND. Division XII.—Southern Counties.									
Channel Islands (*continued*).				Wigtown.		Kirkcudbright.						Dumfries.	
Millbrook, Jersey.		Alderney.		S. Cairn, Stranraer.		Little Ross.		Carsphairn.		Cargen.		Drumlanrig.	
1 ft. 0 in. 50 ft.		10 ft. 0 in. 48 ft.		0 ft. 4 in. 209 ft.		3 ft. 3 in. 125 ft. ?		3 ft. 10 in. 574 ft.		0 ft. 4 in. 80 ft.		.... 191 ft.	
868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·75	1·97	3·12	3·06	4·35	9·00	2·29	4·36	9·31	10·07	4·50	7·08	6·20	6·90
1·28	2·21	1·13	2·48	4·40	5·25	2·97	3·09	6·93	6·95	7·38	8·01	8·00	6·30
1·64	2·63	1·22	2·92	6·25	2·20	3·39	·74	9·38	·78	8·14	·86	7·70	·80
2·57	2·99	2·02	1·75	4·15	5·70	1·96	1·56	4·01	2·38	3·44	1·95	4·00	2·30
1·49	3·34	2·52	4·35	3·85	2·50	2·42	2·12	4·15	1·52	3·00	1·97	3·40	·60
·54	·77	·75	1·18	1·20	2·00	·35	·51	1·07	1·45	·46	1·15	1·00	1·20
·34	·42	·32	·27	·85	3·20	·38	·64	·49	2·15	·56	1·96	·70	1·10
3·88	·88	4·47	·32	4·00	2·60	4·26	1·03	7·58	1·50	5·49	·94	4·10	1·60
2·15	3·21	2·34	3·39	2·50	8·20	1·93	4·03	3·62	9·18	2·76	8·20	2·50	7·70
3·68	3·16	4·38	2·90	6·20	4·60	2·27	1·45	7·93	3·04	5·24	2·46	5·30	1·90
3·13	3·46	1·52	3·04	4·05	9·05	1·55	2·90	7·93	8·72	2·90	6·04	1·10	5·30
4·42	5·50	5·85	5·93	8·50	5·90	6·68	2·49	14·10	10·27	10·48	9·78	6·00	7·80
3·87	30·54	29·64	31·59	50·30	60·20	30·45	24·92	76·50	58·01	54·35	50·40	50·00	43·50

SCOTLAND.

Div. XII.—Southern Counties (*continued*).			Division XIII.—South-Eastern Counties.									
	Dumfries (*continued*).		Roxburgh.		Selkirk.		Peebles.		Berwick.		Haddington.	
	Wanlockhead.		Silverbut Hall, Hawick.		Bowhill Gardens.		N. Esk Reservoir, Penicuick.		Thirlestane.		East Linton	
Height of Rain-gauge above Ground ...... Sea-level......	0 ft. 4 in. 1330 ft.		4 ft. 0 in. 512 ft.		11 ft. 0 in. 537 ft.		0 ft. 6 in. 1150 ft.		0 ft. 3 in. 558 ft.		0 ft. 3 in. 90 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	186
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ...	8·45	10·54	4·00	3·79	4·10	4·30	5·95	2·45	4·30	3·10	2·10	1·7
February ...	10·29	8·15	3·48	3·54	4·97	2·99	4·90	5·00	2·00	2·20	1·10	1·1
March	13·00	1·39	3·67	1·15	4·04	1·00	3·40	1·05	2·20	1·20	1·01	1·0
April	5·37	2·57	3·39	1·32	2·30	1·43	4·30	1·65	2·90	2·00	2·86	1·0
May	5·84	·92	1·74	2·51	2·22	2·93	2·00	2·15	1·50	1·60	1·68	1·7
June	1·02	2·40	1·25	1·17	1·10	1·40	·80	3·30	·60	1·80	·29	1·8
July	2·83	4·17	·68	·58	·33	·54	·65	1·25	·30	·40	·42	·2
August	6·74	1·50	4·19	1·01	3·75	1·04	6·70	·80	3·40	·95	2·11	·9
September ...	2·56	8·88	4·06	5·28	3·60	5·12	3·85	5·55	3·20	4·30	2·72	2·6
October	8·19	3·09	2·13	1·94	2·98	1·07	2·95	2·25	1·95	1·90	·58	1·9
November ...	4·63	8·78	2·08	2·39	3·00	2·43	3·30	3·20	2·30	1·60	·80	·8
December ...	16·77	10·08	5·68	3·62	4·52	3·75	4·55	2·85	4·60	3·20	2·45	·4
Totals	85·69	62·47	36·35	28·30	36·91	28·00	43·35	31·50	29·25	24·25	18·12	15·7

Division XIV.—South-Western Counties (*continued*).												
	Lanark (*continued*).		Ayr.						Renfrew.			
	Hill End House, Shotts.		Girvan.		Auchendrane, Ayr.		Mansfield, Largs.		Nither Place, Mearns.		Greenock.	
Height of Rain-gauge above Ground ...... Sea-level......	7 ft. 0 in. 620 ft.		0 ft. 6 in. 15 ft.		2 ft. 3 in. 93 ft.		0 ft. 6 in. 30 ft.		0 ft. 6 in. 350 ft.		0 ft. 6 in. 50 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	186
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January......	3·98	3·71	6·40	8·25	5·63	4·60	6·10	5·60	8·38	6·00	12·02	9·5
February ...	4·66	4·75	6·10	4·60	5·99	5·48	5·90	5·40	7·75	5·75	11·74	11·4
March	4·00	·75	8·45	1·10	6·49	·67	6·40	1·40	8·12	1·00	9 21	1·0
April	3·17	·72	3 50	2·50	3·52	2·00	3·50	2·60	3·25	2·00	4·52	2·5
May	2·45	1·09	3·00	·90	2·19	1·02	2·30	·70	3·50	1·50	3·78	·8
June	1·58	2·14	·90	1·95	·95	1·87	1·70	1·90	1·75	2·00	2·11	1·8
July	·58	1·53	·85	2·10	·80	2·39	1·30	3·00	·50	2·50	1·05	2·9
August	4·45	1·54	4·70	1·20	6·16	1·47	6·00	1·20	5·88	·75	8·42	1·2
September..	2·47	5·58	1·75	6·50	1·70	6·38	2·30	8·40	3·00	8·00	2·32	10·7
October	3·55	2·01	5·70	3·66	5·86	2·95	5·60	2·00	7·12	2·13	6 52	2·4
November ...	2·86	3·83	5·50	7·10	2·54	7·22	4·20	6·80	5·00	5·75	5·00	8·5
December ...	4·70	3·20	10·65	6·95	7·09	6·80	7·20	7·20	8·75	9·37	10·62	11·4
Totals	38·45	30·85	57·50	46·81	48·92	42·85	52·50	46·20	63·00	46·75	77·31	64·4

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Division XIII.—South-Eastern Counties (*continued*).						Division XIV.—South-Western Counties.							
Edinburgh.						Lanark.							
Glencorse.		Inveresk.		Charlotte-sq., Edinburgh.		Newmains, CastleDouglas.		Auchinraith, Hamilton.		Glasgow Observatory.		Bailliestown.	
0 ft. 6 in. 787 ft.		2 ft. 0 in. 60 ft.		0 ft. 6 in. 230 ft.		0 ft. 4 in. 783 ft.		4 ft. 9 in. 150 ft.		0 ft. 1 in. 180 ft.		0 ft. 3 in. 230 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
5·90	3·50	3·20	2·42	3·61	2·84	7·89	4·25	4·48	2·93	6·55	4·52	7·85	4·35
6·00	4·80	2·47	2·32	2·08	2·67	6·13	6·65	4·05	4·05	5·79	6·32	6·88	6·20
3·90	1·50	2·04	·86	1·95	·79	5·92	·51	3·55	·48	4·19	·94	5·13	·98
4·65	2·00	2·90	1·08	3·28	1·01	4·89	1·76	2·65	·85	3·90	1·48	4·73	1·48
2·60	2·95	1·96	1·64	1·81	2·64	3·26	1·45	1·98	·74	2·93	·99	3·26	1·54
1·20	1·15	·50	1·26	·48	1·74	1·06	1·40	·84	2·28	1·51	2·14	1·35	2·38
·55	·95	·37	·49	·34	·73	·46	·99	·20	1·28	·59	2·66	·45	2·09
5·80	1·25	5·06	·97	4·30	·76	5·26	1·27	3·68	·90	4·60	1·03	6·39	1·42
4·60	5·70	3·92	4·54	3·27	4·33	2·82	5·39	2·47	4·93	3·10	6·25	3·63	7·08
2·90	2·35	1·73	1·82	2·13	1·48	5·75	1·06	3·69	1·21	4·64	1·73	4·79	2·24
3·05	2·70	2·16	1·34	1·45	1·42	3·73	7·67	3·02	3·64	4·10	5·22	4·11	5·32
5·30	3·55	3·81	·94	3·87	1·82	7·81	6·65	4·53	4·52	6·10	5·79	6·54	7·02
46·45	32·40	30·12	19·68	28·57	22·23	54·98	39·05	35·14	27·81	48·00	39·07	55·11	42·10

Division XV.—West Midland Counties.

Dumbarton.				Stirling.		Bute.		Argyll.					
Balloch Castle.		Arddarock, Loch Long.		Polmaise.		Pladda.		Devaar, Campbell-town.		Rhinns of Islay.		M'Arthur's Head.	
0 ft. 4 in. 91 ft.		0 ft. 10 in. 80 ft.		0 ft. 2 in. 12 ft.		3 ft. 3 in. 55 ft. ?		3 ft. 4 in. 75 ft.		3 ft. 0 in. 74 ft. ?		0 ft. 4 in. 106 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
8·92	7·96	12·68	10·89	8·00	5·30	4·70	4·19	5·08	5·73	3·61	2·49	8·20	6·40
7·01	6·20	13·92	10·34	5·10	5·20	5·87	4·27	5·03	5·89	3·67	3·33	11·00	6·90
6·09	1·42	11·09	2·74	4·20	1·10	7·25	1·62	7·21	2·38	4·26	1·10	10·00	2·10
4·35	1·81	6·03	2·14	4·10	1·25	3·07	2·10	2·28	3·33	1·56	2·20	4·20	3·30
2·74	·75	5·79	·57	3·30	·80	3·10	·78	3·80	·47	2·59	·71	5·60	1·00
2·50	2·73	3·53	2·40	1·50	2·30	·90	1·46	·76	1·26	1·22	1·58	2·50	1·60
1·31	2·73	1·38	2·60	·60	2·00	1·28	1·29	·93	2·50	·51	2·27	1·50	3·20
5·56	·92	8·27	·97	5·00	1·00	7·15	1·20	5·50	1·42	4·62	1·16	8·10	1·80
3·06	8·51	4·55	11·79	2·50	5·70	1·52	7·36	2·13	6·47	2·40	4·74	2·50	11·60
5·75	2·37	9·87	3·49	4·00	2·10	5·92	3·30	8·31	3·26	3·98	2·19	9·20	4·20
4·01	6·85	8·01	9·70	3·00	3·10	2·79	6·37	4·02	8·10	4·05	5·20	6·20	9·80
7·48	6·05	13·91	11·72	7·00	6·00	5·65	4·30	5·26	6·36	4·19	4·27	8·00	9·70
58·78	48·30	99·03	69·35	48·30	35·85	49·20	38·74	50·31	47·17	36·66	31·24	77·00	61·60

SCOTLAND.

Division XV.—West Midland Counties (*continued*).

Argyll (*continued*).

Height of Rain-gauge above	Castle Toward.		Airds, Appin.		Callton Mor.		Inverary Castle.		Lismore.		Hynish.	
Ground	4 ft. 0 in.		0 ft. 2 in.		4 ft. 6 in.		0 ft. 1 in.		3 ft. 4 in.		0 ft. 0 in.	
Sea-level......	65 ft.		12 ft.		65 ft.		35 ft.		37 ft.		....	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January......	9·31	6·24	8·50	6·20	8·01	7·06	10·00	7·00	4·82	2·78	7·49	9·52
February ...	6·03	5·66	10·20	6·70	7·87	6·73	14·00	9·00	7·63	4·51	13·29	10·09
March	6·57	1·28	6·50	1·90	7·50	1·91	8·00	3·00	3·39	1·19	12·61	4·46
April	3·52	2·03	3·60	3·40	3·28	2·89	4·00	2·00	2·72	1·94	3·69	3·69
May	3·99	·49	6·80	·40	4·16	·69	6·00	1·00	5·16	·20	6·54	·25
June	1·55	2·71	4·00	2·50	2·40	2·56	4·00	4·00	2·09	1·61	3·94	1·83
July	1·35	4·01	1·70	3·30	1·58	3·45	1·00	4·00	·99	2·53	1·08	3·10
August	6·69	1·18	7·40	1·90	7·16	1·90	8·00	1·50	5·60	1·03	5·70	1·62
September...	2·34	7·73	1·30	9·00	1·86	8·74	2·00	12·00	1·88	3·34	2·26	8·58
October	5·37	2·03	5·90	4·40	7·29	3·93	9·00	6·00	4·11	2·89	8·56	1·80
November ...	4·08	6·08	3·20	8·00	4·80	8·48	6·00	6·50	2·33	5·03	7·81	11·94
December ...	7·47	6·16	8·20	9·10	7·85	7·59	9·00	8·00	5·26	7·22	10·45	9·75
Totals	58·27	45·60	67·30	56·80	63·76	55·93	81·00	64·00	45·98	34·27	83·42	66·63

Division XVI.—East Midland Counties (*continued*).

Perth (*continued*).

Height of Rain-gauge above	Loch Katrine.		Auchterarder House.		Stronvar, Loch Earn Head.		Trinity Gask.		Scone Palace.		Strath-tay, Logierait.	
Ground	0 ft. 6 in.		2 ft. 3 in.		0 ft. 4 in.		0 ft. 1 in.		2 ft. 6 in.		1 ft. 0 in.	
Sea-level......	830 ft.		162 ft.		460 ft.		133 ft.		80 ft.		313 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January ...	11·80	12·90	7·70	5·55	15·40	10·37	6·15	5·78	4·63	4·17	5·35	5·48
February ...	13·80	9·70	4·71	4·15	13·55	10·27	3·08	3·20	2·68	1·95	4·03	3·38
March	10·10	2·20	3·85	·60	11·47	7·15	3·30	1·00	2·80	·94	3·67	·76
April	5·10	1·90	3·85	1·10	6·30	3·30	3·16	1·20	2·54	1·59	4·02	1·30
May	5·90	1·20	2·50	1·10	5·80	1·25	2·88	1·02	1·99	·60	2·44	·73
June	2·90	3·00	·75	2·60	2·52	3·45	1·12	2·68	·45	1·92	1·00	2·11
July	1·50	4·00	·40	1·20	1·05	4·20	·55	1·58	·61	1·15	·58	1·48
August	8·60	1·20	5·10	·80	8·50	1·05	5·40	·68	4·85	1·05	4·81	·88
September ...	3·00	11·80	2·90	4·30	3·90	11·85	2·82	4·92	3·33	4·60	3·03	4·12
October	10·20	4·20	2·65	2·15	9·20	4·67	2·12	2·60	1·35	3·00	2·77	3·29
November ...	6·10	9·50	2·20	1·50	6·60	4·67	1·56	1·55	1·92	·95	3·14	2·50
December ...	15·90	11·80	7·35	5·05	17·30	13·95	6·26	5·10	4·81	2·80	6·27	3·42
Totals	94·90	73·40	43·96	30·10	101·59	76·18	38·40	31·31	31·96	24·72	41·11	29·45

SCOTLAND.

Div. XV.—(*continued*).				Division XVI.—East Midland Counties.									
Argyll (*continued*).				Clackmannan.		Kinross.		Fife.		Perth.			
Corran, Loch Eil.		Ardnamurchan.		Dollar.		Loch Leven Sluice.		Nookton.		Kippenross.		Deanston.	
4 in. 14 ft. ?		3 ft. 6 in. 82 ft.		0 ft. 6 in. 170 ft.		0 ft. 10 in.		0 ft. 6 in. 80 ft.		0 ft. 4 in. 100 ft.		0 ft. 4 in. 130 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
15·00	8·90	4·60	4·76	6·57	6·05	5·40	4·90	3·68	3·61	6·40	5·85	8·37	6·51
21·50	9·98	7·18	3·78	5·00	4·02	3·30	4·20	2·28	2·46	3·10	3·80	5·37	5·87
11·53	2·20	5·57	1·56	4·14	·43	3·00	·80	1·90	·94	3·50	·55	4·88	1·00
3·83	3·80	2·16	2·42	4·46	2·04	3·20	1·60	2·89	1·64	3·00	·70	3·91	1·42
6·50	·20	3·92	·11	2·94	2·12	2·60	1·20	1·98	1·56	2·30	·60	2·90	1·04
5·75	3·35	2·50	·60	·84	2·96	·50	2·80	·50	2·53	·25	2·30	1·29	2·74
2·40	4·80	1·15	1·35	1·64	2·43	·30	·60	·25	1·31	·25	1·40	·84	2·19
10·50	1·70	4·17	1·08	4·93	1·07	5·40	1·10	3·92	·86	4·40	·55	6·46	·76
1·80	12·15	1·01	4·95	2·89	4·65	3·60	6·10	3·04	5·09	2·30	5·65	2·64	6·90
9·05	4·60	4·43	5·60	2·81	3·42	2·50	2·60	1·89	2·26	4·20	2·50	4·82	2·72
5·65	14·55	2·66	5·19	3·28	2·62	1·60	2·00	1·25	1·14	3·00	2·70	3·11	4·14
10·75	12·15	4·66	4·46	6·22	4·05	6·50	3·20	4·71	1·58	6·60	5·20	6·81	5·25
104·26	78·38	44·01	35·86	45·72	35·86	37·90	31·10	28·29	24·98	39·30	31·80	51·40	40·54

Division XVI.—East Midland Counties (*continued*).						Division XVII.—North-Eastern Counties.							
Forfar.						Kincardine.		Aberdeen.					
Dundee, Necropolis.		Arbroath.		Montrose.		The Burn, Brechin.		Braemar.		Aberdeen.		Castle Newe.	
0 ft. 5 in. 167 ft.		2 ft. 0 in. 61 ft.		2 ft. 0 in. 200 ft.		0 ft. 6 in. 237 ft.		0 ft. 9 in. 1114 ft.		0 ft. 4 in. 95 ft.		1 ft. 0 in. 915 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·60	4·00	3·63	4·05	2·66	7·15	4·90	5·10	4·65	4·71	2·75	3·55	3·27	3·10
1·35	1·25	1·85	1·06	1·97	1·31	2·10	2·30	3·19	2·28	1·63	1·17	1·98	1·35
1·45	·80	1·92	1·04	2·27	·83	2·00	1·50	2·64	1·13	1·72	1·89	1·36	2·23
3·40	1·55	2·69	1·57	3·78	2·30	3·30	1·50	2·80	2·41	2·40	2·23	4·16	2·98
1·55	·85	1·97	1·76	2·24	1·67	1·90	·70	1·81	·70	1·49	1·47	·77	1·50
·25	2·60	·44	2·53	·58	2·28	·70	2·90	·93	2·17	·60	1·79	·51	2·21
·20	·95	·30	·81	·21	1·56	·30	1·20	·29	·94	·72	·85	·44	·50
5·45	·95	5·26	·95	5·89	2·58	4·20	1·20	5·58	1·31	6·43	1·32	6·02	1·60
4·40	6·05	4·68	5·13	6·50	5·52	4·90	5·00	4·14	4·77	3·56	4·60	4·94	3·90
1·35	2·95	2·33	2·87	3·35	5·07	2·70	4·60	2·52	4·59	1·86	5·74	2·12	5·00
1·50	·80	1·34	·55	·49	2·11	1·40	·80	2·24	2·90	·40	1·54	1·84	2·75
5·00	1·90	7·22	1·41	7·85	2·49	7·10	3·30	6·44	3·75	4·96	2·92	3·06	2·69
29·50	24·65	33·63	23·73	37·79	34·87	35·50	30·10	37·23	31·66	28·52	29·07	30·47	29·81

SCOTLAND.

	Division XVII.—North-Eastern Counties (*continued*).				Div. XVIII.—North-Western Counties.							
	Aberdeen (*continued*).		Banff.		Ross and Cromarty.							
Height of Rain-gauge above	Tillydesk, Ellon.		Gordon Castle.		Inverinate House, Loch Alsh.		Lochbroom.		Cromarty.		Ardross Castle, Alness.	
Ground ...... / Sea-level......	0 ft. 4 in. 349 ft.		1 ft. 6 in. 70 ft.		3 ft. 0 in. 150 ft.		0 ft. 8 in. 47 ft.		3 ft. 4 in. 28 ft.		1 ft. 0 in. 450 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	3·12	3·36	3·47	1·87	11·12	7·80	10·02	5·25	3·68	·90	7·25	2·83
February ...	2·08	2·22	3·85	2·76	19·72	9·05	12·72	6·89	3·81	2·46	4·79	5·61
March	1·87	2·77	1·10	1·77	9·38	3·10	5·55	2·63	1·65	·59	3·35	2·46
April	2·63	2·11	2·86	2·09	2·25	3·20	2·48	2·41	1·76	1·27	2·70	2·13
May	1·32	1·91	·72	2·86	5·35	·65	2·26	1·74	·94	1·02	1·79	2·12
June	1·11	1·84	1·06	1·65	4·75	1·80	3·88	1·67	·75	·87	2·09	1·49
July	·59	·66	·74	·95	3·00	4·75	·58	2·46	·78	·35	·25	1·41
August	4·30	1·50	4·70	2·04	9·80	2·43	8·26	1·74	4·38	1·18	7·64	1·28
September ...	5·06	6·34	5·05	4·10	·83	10·44	2·07	6·17	3·16	3·37	5·40	5·24
October	2·56	6·62	2·14	4·90	10·52	5·65	8·52	5·65	1·42	3·60	3·68	5·36
November ...	2·43	3·60	2·08	3·32	5·55	10·50	4·52	10·59	1·09	2·12	2·60	4·94
December ...	4·16	2·43	1·46	2·53	9·47	9·75	4·63	5·63	1·96	2·32	3·45	3·94
Totals	31·23	35·42	29·23	30·84	91·74	69·12	65·49	52·83	25·38	20·05	44·99	38·81

	Div. XVIII. (*continued*).				Division XIX.—Northern Counties.							
	Inverness (*continued*).				Sutherland.						Caithness.	
Height of Rain-gauge above	Grantown.		Laggan.		Dunrobin.		House of Tongue.		Cape Wrath.		Nosshead.	
Ground ...... / Sea-level......	1 ft. 2 in. 712 ft.		0 ft. 9 in. 821 ft.		0 ft. 3 in. 6 ft.		0 ft. 1 in. 33 ft.		3 ft. 6 in. 355 ft.		3 ft. 4 in. 127 ft. ?	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	4·82	1·88	10·63	7·31	4·81	1·60	2·40	3·00	4·72	3·11	2·39	1·67
February ...	3·06	2·62	10·62	9·07	4·80	4·35	6·50	6·50	8 14	4·89	3·53	3·37
March	1·50	1·94	7·01	5·08	2·10	2·00	2·80	2·30	4·30	1·48	2·34	1·77
April	2·49	3·30	3·77	2·68	1·22	1·90	2·70	4·00	2·54	2·30	1·61	1·85
May	·93	1·99	2·27	·90	1·40	·20	1·80	1·50	2·32	1·24	1·31	1·37
June	·75	2·44	2·75	1·92	1·58	·60	1·20	·70	2·93	1·90	1·15	1·48
July	·80	·70	·71	1·83	·25	·70	·30	2·00	1·33	3·04	·89	·60
August	4·16	2·86	6·69	1·34	5·20	1·30	8·00	1·30	8·58	3·66	4·08	2·26
September ...	3·34	4·10	1·65	6·56	2·85	4·20	1·50	6·00	2·25	6·17	1·21	4·88
October	1·97	5·13	6·29	5·29	3·10	4·10	4·50	4·90	5·11	3·11	2·38	2·49
November ...	2·61	3·61	4·25	9·48	1·70	4·60	3·50	8·40	1·93	6·11	1·52	5·16
December ...	2·19	2·97	6·48	7·80	2·10	3·00	3·50	3·20	4·55	3·57	3·88	1·45
Totals	28·62	33·54	63·12	59·26	31·11	28·55	38·70	43·80	48·70	40·58	26·29	28·35

SCOTLAND.

Division XVIII.—North-Western Counties (*continued*).

Inverness.													
Oronsay.		Raasay.		Barrahead.		Ushenish, South Uist.		Culloden.		Island Glass.		Corrimony, Urquhart.	
0 ft. 6 in. 15 ft. ?		1 ft. 4 in. 80 ft.		3 ft. 0 in. 640 ft. ?		0 ft. 4 in. 157 ft.		3 ft. 0 in. 104 ft.		3 ft. 4 in. 50 ft.		0 ft. 6 in. 550 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
10·70	6·00	12·30	9·20	4·14	5·39	5·29	1·60	5·58	2·21	5·85	4·79	9·30	4·70
19·10	11·50	16·60	11·65	4·15	4·01	9·97	4·40	3·88	2·76	9·36	8·35	8·20	4·60
10·10	3·00	11·70	3·60	3·83	1·29	5·47	1·47	2·05	·94	5·95	2·02	4·00	·60
2·70	3·90	3·70	3·10	·85	·91	2·30	1·86	2·26	1·48	2·80	1·72	1·70	1·20
6·80	2·20	5·10	1·55	1·73	·39	3·35	·26	1·14	2·01	3·61	·49	1·20	1·00
6·90	2·70	6·10	1·55	1·14	1·60	1·79	1·83	·78	1·69	4·31	1·81	·50	1·20
5·60	7·30	6·55	5·20	·79	2·21	1·07	3·24	·40	·44	1·90	3·68	0·00	1·10
10·30	5·00	7·05	1·95	4·10	·14	4·89	1·85	6·62	1·48	5·36	2·62	5·80	·30
1·20	11·20	2·80	11·95	·90	4·37	1·50	5·81	3·55	3·76	2·19	6·05	2·10	7·90
11·20	5·00	11·00	8·30	4·02	2·44	4·14	5·39	1·90	3·31	5·16	3·24	4·90	6·60
5·00	8·00	7·85	10·45	2·55	2·45	2·64	10·39	1·31	2·91	3·71	6·55	2·40	8·00
8·20	4·90	12·50	14·05	3·76	1·99	4·56	3·98	2·15	2·67	5·31	5·05	4·90	9·30
97·80	70·70	103·25	82·55	31·96	27·19	46·97	42·08	31·62	25·66	55·51	46·37	45·00	46·50

Division XIX.—Northern Counties (*continued*).

Caithness (*continued*).				Orkney.				Shetland.					
Holburnhead.		Pentland Skerries.		Balfour Castle		Sandwick.		Sumburghead.		Bressay.		East Yell.	
0 ft. 4 in. 60 ft.		3 ft. 3 in. 72 ft.		0 ft. 3 in. 50 ft.		2 ft. 0 in. 78 ft.		3 ft. 4 in. 265 ft.		0 ft. 4 in. 60 ft.		1 ft. 0 in. 176 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
3·41	1·08	2·67	2·22	4·20	3·40	4·50	3·83	4·20	4·31	4·28	3·73	4·46	4·93
4·32	4·14	3·78	3·95	4·40	4·30	5·81	4·04	3·70	1·82	6·07	2·58	7·74	4·88
2·15	3·45	2·56	2·47	3·80	2·30	4·27	2·85	2·36	1·14	3·60	1·99	4·39	5·17
2·52	2·47	2·17	1·61	2·50	3·30	3·31	3·75	2·23	1·35	2·85	2·10	4·09	2·64
1·03	·90	1·18	1·39	1·00	·60	1·51	1·03	2·21	1·41	2·27	1·78	3·51	2·77
1·11	1·15	1·60	1·09	1·80	1·10	2·80	1·97	1·86	1·43	2·12	1·22	3·82	1·25
·68	1·75	1·07	1·23	1·30	1·80	1·35	3·20	·67	1·67	·85	2·23	1·80	3·66
6·50	2·70	5·34	1·57	6·60	1·80	5·32	2·37	7·19	1·46	8·74	2·40	5·96	3·81
1·55	5·70	·99	5·00	1·30	7·50	1·41	6·60	1·43	4·37	1·28	4·78	·86	3·90
2·41	2·90	3·17	2·24	5·50	2·60	5·34	3·33	2·32	2·53	4·02	1·12	6·51	4·05
2·11	6·20	1·42	4·64	2·20	6·00	2·66	6·70	1·42	4·01	1·67	3·81	2·89	7·57
2·68	1·90	2·48	2·34	4·30	3·50	5·15	3·76	4·90	2·14	6·77	3·12	5·32	5·14
30·47	34·34	28·43	29·75	38·90	38·20	43·43	43·43	34·49	27·64	41·52	30·86	51·35	49·77

IRELAND.

	Division XX.—Munster.										Div. XXI.—Leinster.	
	Cork.		Kerry.		Waterford.		Tipperary.		Clare.		Carlow.	
Height of Rain-gauge above	Cork, Queen's College.		Valentia.		Waterford.		Ballykisteen.		Killaloe.		Fenagh, Bagnalstown.	
Ground	6 ft. 0 in.		1 ft. 2 in.		4 ft. 0 in.		1 ft. 1 in.		5 ft. 0 in.		1 ft. 0 in.	
Sea-level......	65 ft.		10 ft.		60 ft.?		350 ft.		123 ft.		340 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	6·82	8·59	6·59	9·56	5·52	8·42	3·79	5·04	3·93	5·01	2·92	6·52
February ...	2·16	2·96	4·78	4·53	2·82	2·34	2·29	3·11	4·41	5·96	1·36	2·29
March	3·28	2·85	5·91	3·54	3·63	2·55	3·83	2·73	5·12	3·86	2·31	2·09
April	2·97	2·58	3·34	4·12	3·04	2·00	2·77	2·91	3·22	3·89	2·35	2·40
May	2·35	5·48	3·53	2·79	2·61	4·87	1·29	3·96	3·08	4·20	2·19	2·76
June	·95	·18	1·66	1·06	·93	·32	1·81	1·49	1·97	1·45	3·32	1·09
July	1·20	2·07	3·35	3·81	1·64	1·22	1·36	1·55	1·41	2·80	1·26	1·55
August	5·92	·87	3·46	1·89	6·39	1·22	7·10	1·87	5·80	1·02	4·43	1·03
September ...	5·98	5·15	2·83	8·05	6·90	5·98	3·36	5·25	2·98	8·87	4·87	5·79
October	2·87	·67	5·89	2·64	3·72	·84	3·12	1·13	6·20	1·52	2·36	·72
November ...	5·83	2·44	6·72	4·19	4·58	2·23	2·63	3·85	2·35	5·49	2·90	2·56
December ...	9·99	7·12	10·11	8·37	9·81	5·41	6·26	6·87	6·67	6·50	6·86	3·60
Totals	50·32	40·96	58·17	54·55	51·59	37·40	39·61	39·76	47·14	50·57	37·13	32·40

	Division XXII.—Connaught (*continued*).						Division XXIII.—Ulster.					
	Roscommon.		Sligo.				Cavan.		Enniskillen.		Antrim.	
Height of Rain-gauge above	Holywell.		Doo Castle.		Hazlewood, Sligo.		Red Hills, Belturbet.		Florence Court.		Antrim.	
Ground	5 ft. 6 in.		1 ft. 0 in.		2 ft. 4 in.		0 ft. 9 in.		11 ft. 4 in.		1 ft. 0 in.	
Sea-level......	....		....		47 ft.		....		300 ft.		150 ft.	
	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January	3·06	3·30	5·11	4·68	4·80	3·85	4·11	3·01	7·30	5·66	2·56	2·50
February ...	2·99	3·23	3·69	5·21	3·45	4·99	3·19	4·23	3·47	6·26	2·25	3·36
March	3·28	2·35	4·24	3·43	4·69	3·18	3·58	2·88	5·27	2·75	3·50	1·33
April	1·90	2·56	1·49	3·34	1·41	2·69	2·38	2·67	1·78	2·80	1·62	2·55
May	2·28	2·48	3·23	2·72	2·14	2·11	2·52	2·88	2·69	2·97	1·73	1·85
June	2·32	1·09	1·81	1·11	1·57	·98	3·01	1·06	2·37	·68	·59	·36
July	1·07	1·54	1·55	2·23	1·93	1·67	·96	1·65	·49	2·58	·57	1·97
August	4·23	1·50	3·80	1·34	4·05	2·41	4·26	1·46	3·62	1·29	4·10	1·62
September...	3·32	6·91	3·05	4·07	1·52	3·03	1·88	3·32	1·78	4·35	1·12	3·02
October	3·52	1·03	4·11	2·34	4·79	2·36	2·79	1·38	5·82	1·95	1·92	1·33
November ...	2·50	2·78	4·58	6·18	4·16	6·48	2·94	3·78	5·77	6·11	2·66	4·13
December ...	5·30	4·96	7·81	6·19	5·64	6·56	5·10	3·60	8·81	7·08	3·89	2·64
Totals	35·77	33·73	44·47	42·84	40·15	40·31	36·72	31·92	49·17	44·48	26·51	26·66

IRELAND.

Division XXI.—Leinster (*continued*).										Division XXII.—Connaught.			
Queen's Co.		King's Co.				Wicklow.		Dublin.		Galway.			
Portarlington.		Birr Castle, Parsonstown.		Tullamore.		Fassaroe, Bray.		Black Rock.		Cregg Park, Gort.		Galway, Queen's College.	
1 ft. 2 in. 736 ft.		0 ft. 3 in. 200 ft.		3 ft. 0 in. 235 ft.		5 ft. 0 in. 250 ft.		29 ft. 0 in. 90 ft.		3 ft. 0 in. 120 ft.		6 ft. 0 in. 25 ft.	
1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
2·25	4·53	3·17	4·06	2·29	3·53	4·09	6·53	3·99	5·24	3·27	4·09	5·29	4·27
2·27	2·24	2·45	2·57	1·96	2·00	1·90	2·19	1·82	1·09	3·46	3·99	5·25	6·12
2·71	2·09	3·12	1·78	2·83	1·92	3·13	3·69	2·19	1·83	4·08	2·84	5·38	3·44
2·14	1·82	2·20	2·88	1·06	2·24	2·62	1·75	2·08	1·10	2·45	2·87	2·28	3·41
1·78	3·14	2·17	3·72	2·34	2·21	1·42	8·22	1·19	7·03	2·25	3·97	3·74	4·80
2·32	·83	1·55	1·51	1·96	·68	1·43	1·25	1·02	1·08	·80	1·43	1·74	1·60
1·10	1·57	2·44	2·15	1·13	1·50	1·00	·72	·77	·43	1·27	1·80	2·51	3·87
4·09	1·22	4·90	2·07	4·34	1·26	6·55	·76	5·17	·86	5·37	1·29	3·93	1·47
2·89	3·88	2·82	6·15	2·48	3·75	4·98	4·76	3·52	4·08	2·82	8·24	2·41	8·46
2·08	2·68	2·29	·62	1·96	2·49	1·85	2·44	1·00	1·18	5·10	1·18	6·16	1·67
1·67	2·66	2·31	2·92	2·33	2·84	3·65	2·49	3·19	2·21	3·16	3·90	2·63	5·01
5·10	3·39	4·21	5·13	3·88	4·04	9·09	4·16	6·73	3·56	6·45	6·45	6·49	8·07
30·40	30·05	33·63	35·56	28·56	28·46	41·71	38·96	32·67	29·69	40·48	42·05	47·81	52·19

Division XXIII.—Ulster (*continued*).					
Antrim (*continued*).				Donegal.	
Belfast, Queen's College.		Ballymoney.		Letterkenny.	
7 ft. 4 in. 68 ft.		7 ft. 0 in. 170 ft.		1 ft. 8 in. 108 ft.	
1868.	1869.	1868.	1869.	1868.	1869.
in.	in.	in.	in.	in.	in.
2·86	3·86	4·25	3·24	8·14	5·56
2·96	4·45	2·58	4·39	4·58	6·13
3·85	2·08	4·35	2·10	6·61	3·61
2·56	1·93	2·03	2·09	2·66	2·50
2·13	1·85	2·80	1·54	3·44	3·46
3·35	1·29	·69	2·01	3·31	2·50
·57	2·02	·67	1·85	·71	3·15
4·58	1·81	4·79	2·36	6·31	1·30
1·86	4·96	1·25	4·20	2·79	5·73
2·31	1·35	2·65	1·97	4·63	4·30
2·69	4·30	4·45	6·86	7·02	8·61
4·86	2·67	4·73	4·03	6·36	6·00
31·58	32·57	35·24	36·64	56·56	52·85

Abstract, and results, of experiments on the decrease of rainfall corresponding to small elevations of the rain-gauge above the ground.

Table I.—Total depth of Rain collected in each month. Castle House, Calne, Wilts; lat. 51° 27′ N., long. 1° 59′ W.

Elevation Series. 8 inches diameter.

Date.	Isolated level.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-inch gauge.
1863.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
August	...	2·989	2·989	2·940	2·940	2·941	2·919	2·883	2·860	2·833	2·731
September ...	...	3·018	3·038	3·024	3·024	3·011	2·968	2·956	2·919	2·848	2·791
October	...	3·698	3·653	3·624	3·585	3·554	3·528	3·492	3·457	3·460	3·341
November (*a*)	...	2·379	2·362	2·252	2·186	2·154	2·122	2·096	2·050	2·108	1·960
December ...	...	1·250	1·249	1·225	1·156	1·124	1·098	1·082	1·057	1·048	·975
		13·334	13·291	13·065	12·891	12·784	12·635	12·509	12·343	12·297	11·798
1864.											
January	...	1·808	1·814	1·729	1·676	1·629	1·603	1·574	1·543	1·531	1·500
February ...	...	1·216	1·187	1·179	1·097	1·081	1·060	1·044	1·010	1·003	·957
March	...	2·711	2·687	2·610	2·546	2·506	2·474	2·406	2·414	2·425	2·348
April	...	1·920	1·891	1·859	1·860	1·834	1·818	1·797	1·782	1·759	1·732
May (*b*)	...	1·152	1·149	1·162	1·116	1·107	1·095	1·083	1·076	1·061	1·025
June	...	1·726	1·695	1·692	1·666	1·630	1·620	1·606	1·582	1·543	1·472
July	...	·686	·691	·679	·690	·676	·675	·656	·653	·623	·591
August	...	·678	·670	·651	·658	·647	·638	·626	·622	·607	·568
September ...	...	2·797	2·692	2·741	2·687	2·647	2·617	2·576	2·525	2·452	2·328
October (*c*) ...	...	2·226	2·193	2·182	2·178	2·140	2·130	2·117	2·082	1·993	1·986
November ...	...	1·990	1·968	1·899	1·882	1·836	1·818	1·800	1·747	1·711	1·668
December (*d*)	...	2·735	2·701	2·657	2·631	2·583	2·538	2·553	2·508	2·458	2·373
		21·645	21·338	21·040	20·687	20·316	20·086	19·838	19·544	19·166	18·548
1865.											
January	...	3·893	3·863	3·581	3·517	3·163	3·225	3·203	3·062	3·159	3·134
February (*e*) .	...	3·482	3·528	3·019	2·933	2·849	2·826	2·806	2·634	2·679	2·546
March	...	1·007	·973	·912	·897	·868	·873	·851	·830	·842	·808
April	·745	·782	·763	·736	·729	·720	·723	·706	·706	·693	·658
May	2·338	2·387	2·325	2·272	2·277	2·275	2·271	2·222	2·187	2·178	2·095
June	1·583	1·577	1·569	1·563	1·563	1·565	1·560	1·540	1·538	1·519	1·458
July (*f*)	3·002	2·993	2·977	2·921	2·897	2·901	2·904	2·879	2·827	2·722	2·780
August	4·295	4·280	4·240	4·211	4·203	4·203	4·223	4·176	4·147	4·082	3·974
September ...	·126	·128	·128	·120	·128	·138	·152	·143	·151	·144	·106
October (*g*)...	5·603	5·601	5·577	5·536	5·525	5·503	5·495	5·420	5·425	5·416	5·249
November ...	3·389	3·454	3·402	3·327	3·279	3·207	3·221	3·139	3·097	3·094	3·026
December ...	2·517	2·705	2·626	2·557	2·478	2·413	2·404	2·364	2·301	2·351	2·257
		32·289	31·971	30·755	30·426	29·805	29·877	29·449	28·905	28·879	28·091
1866.											
January	4·240	4·582	4·297	3·914	3·625	3·604	3·646	3·429	3·341	3·413	3·342
February ...	4·340	4·509	4·395	4·257	4·138	4·078	4·019	3·863	3·831	3·822	3·707
March	2·167	2·183	2·151	2·100	2·055	2·028	1·959	1·884	1·931	1·995	1·864
April	2·282	2·318	2·249	2·182	2·148	2·145	2·125	2·070	2·090	2·090	1·991
May	1·185	1·210	1·174	1·130	1·131	1·132	1·129	1·108	1·081	1·085	1·000
June	3·056	3·084	3·026	2·969	2·997	2·984	2·992	2·948	2·903	2·912	2·853
July	1·488	1·504	1·477	1·434	1·451	1·454	1·448	1·444	1·394	1·436	1·397
August	2·476	2·495	2·459	2·379	2·408	2·380	2·383	2·384	2·350	2·368	2·288
September (*h*)	6·866	6·910	6·790	6·716	6·683	6·684	6·663	6·575	6·515	6·560	6·509
October	2·198	2·202	2·159	2·130	2·137	2·132	2·122	2·107	2·098	2·086	1·992
November ...	2·482	2·537	2·435	2·345	2·351	2·289	2·250	2·173	2·070	2·003	2·035
December ..	3·144	3·270	3·133	2·945	2·921	2·880	2·820	2·750	2·662	2·587	2·619
	35·924	36·804	35·745	34·501	34·043	33·790	33·556	32·735	32·266	32·357	31·597

TABLE I. (*continued*).

Date.	Iso-lated level.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-inch gauge.
	Elevation Series. 8 inches diameter.										
1867.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
January (*i*)...	3·671	3·880	3·626	3·514	3·359	3·292	3·207	3·166	3·063	3·003	2·868
February ...	2·210	2·278	2·182	2·052	1·952	1·966	1·918	1·837	1·757	1·696	1·710
March	3·526	4·315	3·930	3·502	3·268	3·208	3·191	3·191	3·104	2·785	3·300
April	3·343	3·354	3·328	3·228	3·225	3·194	3·145	3·059	2·968	2·935	2·866
May	1·832	1·812	1·817	1·793	1·789	1·777	1·771	1·764	1·750	1·742	1·640
June	2·245	2·243	2·235	2·197	2·187	2·186	2·169	2·183	2·125	2·115	2·000
July	3·788	3·691	3·736	3·686	3·684	3·630	3·678	3·654	3·615	3·601	3·404
August	3·078	3·056	3·054	2·994	3·019	2·993	3·003	2·995	2·967	2·955	2·883
September ...	1·843	1·813	1·840	1·799	1·793	1·782	1·781	1·774	1·748	1·715	1·631
October	2·899	2·913	2·898	2·871	2·862	2·832	2·815	2·786	2·755	2·717	2·657
November ...	1·324	1·317	1·275	1·264	1·266	1·261	1·247	1·218	1·209	1·192	1·130
December ...	1·810	1·840	1·843	1·730	1·670	1·620	1·578	1·560	1·535	1·530	1·510
	31·569	32·512	31·764	30·630	30·074	29·791	29·503	29·187	28·596	27·986	27·599

REMARKS.

(*a*) 1863, November. 20 ft. 8 in.-gauge, $\frac{1}{4}$ in. out of level till 14th.
(*b*) 1864, May. Level, 2 in. and 6 in. Collected a large quantity of dew between 12th and 21st.
(*c*) 1864, October. Level, 2 in. and 6 in. Very troublesome with leaves.
(*d*) 1865, January. Intense frost on 29th, min. 6°. Burst all the elevation-gauges from "2 ft." upwards; they were all frozen up from 24th to 29th, and melted on the latter day. The "level" and "2 in." were buried in the snow.
(*e*) 1865, February 17th. Impossible to measure the three lowest gauges accurately, they being buried in the snow.
(*f*) 1865, July 7th and 8th. Conducting-pipe of 10-ft. gauge leaked: the total measured was 2·577 in.; and it is calculated that the loss was ·140 and ·110, which has been added to prevent a break in the series.
(*g*) 1865, October. "Level" and "2 in." Very troublesome with leaves.
(*h*) 1866, October. Pipe of 20 ft. 5-in. gauge found to leak slightly and repaired; 0·45 added to September fall, being the computed loss.
(*i*) 1867. Level and 2-in. gauges buried under snow; the amounts measured were 7·880 and 7·626, from each of which 4 inches has been deducted.

TABLE II.—Ratio of Rain collected at various heights to that at 1 foot.

Date.	Iso-lated level.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-inch gauge.
	Elevation Series. 8 inches diameter.										
1863.											
August	...	1·02	1·02	1·00	1·00	1·00	·99	·98	·97	·96	·93
September	...	1·00	1·00	1·00	1·00	1·00	·98	·98	·97	·94	·92
October	...	1·03	1·02	1·01	1·00	·99	·98	·97	·96	·96	·93
November	...	1·09	1·08	1·03	1·00	·98	·97	·96	·94	·96	·90
December	...	1·08	1·08	1·06	1·00	·97	·95	·94	·92	·91	·84
Mean	...	1·044	1·040	1·020	1·000	·988	·974	·966	·952	·946	·904

TABLE II. (*continued*).

Elevation Series. 8 inches diameter.											
Date.	Isolated level.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-inch gauge.
1864.											
January	...	1·08	1·08	1·03	1·00	·97	·96	·94	·92	·91	·90
February	...	1·11	1·08	1·07	1·00	·99	·97	·95	·92	·91	·87
March	...	1·06	1·06	1·02	1·00	·98	·97	·94	·95	·95	·92
April	...	1·03	1·02	1·00	1·00	·99	·98	·97	·96	·95	·93
May	...	1·03	1·03	1·04	1·00	·99	·98	·97	·96	·95	·92
June	...	1·04	1·02	1·02	1·00	·98	·97	·96	·95	·93	·88
July	...	·99	1·00	·99	1·00	·98	·98	·95	·95	·90	·86
August	...	1·03	1·02	·99	1·00	·98	·97	·95	·94	·92	·86
September	...	1·04	1·00	1·02	1·00	·99	·97	·96	·94	·91	·87
October	...	1·02	1·01	1·00	1·00	·98	·98	·97	·96	·92	·91
November	...	1·06	1·05	1·01	1·00	·98	·97	·96	·93	·91	·89
December	...	1·04	1·03	1·01	1·00	·98	·96	·97	·95	·93	·90
Mean	...	1·044	1·033	1·017	1·000	·983	·972	·958	·944	·924	·893
1865.											
January	...	1·11	1·10	1·02	1·00	·90	·92	·91	·87	·90	·89
February	...	1·19	1·20	1·03	1·00	·97	·96	·96	·90	·91	·87
March	...	1·12	1·08	1·02	1·00	·97	·97	·95	·93	·94	·90
April	1·02	1·07	1·05	1·01	1·00	·99	·99	·97	·97	·95	·90
May	1·03	1·05	1·02	1·00	1·00	1·00	1·00	·98	·96	·96	·92
June	1·01	1·01	1·00	1·00	1·00	1·00	1·00	·99	·98	·97	·93
July	1·04	1·03	1·03	1·01	1·00	1·00	1·00	·99	·98	·94	·96
August	1·02	1·02	1·01	1·00	1·00	1·00	1·00	·99	·99	·97	·95
September	·98	1·00	1·00	·94	1·00	1·07	1·18	1·11	1·18	1·12	·83
October	1·01	1·01	1·01	1·00	1·00	1·00	·99	·98	·98	·98	·95
November	1·03	1·05	1·04	1·01	1·00	·98	·98	·96	·94	·94	·92
December	1·02	1·09	1·06	1·03	1·00	·97	·97	·95	·93	·95	·91
Mean	...	1·063	1·050	1·006	1·000	·988	·997	·978	·968	·961	·911
1866.											
January	1·17	1·26	1·19	1·08	1·00	·99	1·01	·95	·92	·94	·92
February	1·05	1·09	1·06	1·03	1·00	·99	·97	·93	·93	·92	·90
March	1·06	1·06	1·05	1·02	1·00	·99	·95	·92	·94	·97	·91
April	1·06	1·08	1·05	1·02	1·00	1·00	·99	·96	·97	·97	·93
May	1·05	1·07	1·04	1·00	1·00	1·00	1·00	·98	·96	·96	·88
June	1·02	1·03	1·01	·99	1·00	1·00	1·00	·98	·97	·97	·95
July	1·03	1·04	1·02	·99	1·00	1·00	1·00	1·00	·96	·99	·96
August	1·03	1·04	1·02	·99	1·00	·99	·99	·99	·98	·98	·95
September	1·03	1·03	1·02	1·00	1·00	1·00	1·00	·98	·98	·98	·97
October	1·03	1·03	1·01	1·00	1·00	1·00	·99	·99	·98	·98	·93
November	1·06	1·08	1·04	1·00	1·00	·97	·96	·92	·88	·85	·87
December	1·08	1·12	1·07	1·01	1·00	·99	·97	·94	·91	·88	·90
Mean	1·056	1·078	1·048	1·011	1·000	·993	·986	·962	·948	·949	·923
1867.											
January	1·09	1·16	1·08	1·05	1·00	·98	·95	·94	·91	·89	·85
February	1·13	1·17	1·12	1·05	1·00	1·01	·98	·94	·90	·87	·88
March	1·08	1·32	1·20	1·07	1·00	·98	·98	·98	·95	·85	1·01
April	1·04	1·04	1·03	1·00	1·00	·99	·98	·95	·92	·91	·89
May	1·02	1·01	1·02	1·00	1·00	·99	·99	·99	·98	·97	·92
June	1·03	1·03	1·02	1·01	1·00	1·00	·99	1·00	·97	·97	·91
July	1·03	1·00	1·01	1·00	1·00	1·00	1·00	·99	·98	·98	·92
August	1·02	1·01	1·01	·99	1·00	·99	·99	·99	·98	·98	·95
September	1·03	1·01	1·03	1·00	1·00	1·00	·99	·99	·98	·96	·91
October	1·01	1·02	1·01	1·00	1·00	·99	·98	·97	·96	·95	·93
November	1·05	1·04	1·01	1·00	1·00	1·00	·99	·96	·96	·94	·89
December	1·08	1·10	1·10	1·04	1·00	·97	·95	·93	·92	·92	·90
Mean	1·051	1·076	1·053	1·018	1·000	·992	·981	·969	·951	·933	·913

TABLE III.—Ratio of Rain collected at various heights to that in "pit gauge."

Elevation Series. 8 inches diameter.											
Date.	Isolated level.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-inch gauge.
1865.											
April	1·00	1·05	1·02	·99	·98	·97	·97	·95	·95	·93	·88
May	1·00	1·02	·99	·97	·97	·97	·97	·95	·94	·93	·90
June	1·00	1·00	·99	·99	·99	·99	·99	·97	·97	·96	·92
July	1·00	1·00	·99	·97	·96	·97	·97	·96	·94	·91	·93
August	1·00	1·00	·99	·98	·98	·98	·98	·97	·96	·95	·93
September	1·00	1·02	1·02	·95	1·02	1·10	1·21	1·14	1·20	1·14	·84
October	1·00	1·00	1·00	·99	·99	·98	·98	·97	·97	·97	·94
November	1·00	1·02	1·00	·98	·97	·95	·95	·93	·91	·91	·89
December	1·00	1·07	1·04	1·02	·98	·96	·95	·94	·91	·93	·90
	1·000	1·020	1·004	·982	·982	·986	·997	·976	·972	·959	·903
1866.											
January	1·00	1·08	1·01	·92	·86	·85	·86	·81	·79	·80	·79
February	1·00	1·04	1·01	·98	·95	·94	·93	·89	·88	·88	·85
March	1·00	1·01	·95	·97	·95	·94	·90	·87	·89	·92	·86
April	1·00	1·02	·99	·96	·94	·94	·93	·91	·92	·92	·87
May	1·00	1·02	·99	·95	·95	·95	·95	·93	·91	·91	·84
June	1·00	1·01	·99	·97	·98	·98	·98	·96	·95	·95	·93
July	1·00	1·01	·99	·96	·97	·98	·97	·97	·94	·96	·88
August	1·00	1·01	·99	·96	·97	·96	·96	·96	·95	·96	·92
September	1·00	1·01	·99	·98	·97	·97	·97	·96	·95	·96	·95
October	1·00	1·00	·98	·97	·97	·97	·97	·96	·95	·95	·91
November	1·00	1·02	·98	·95	·95	·92	·91	·88	·83	·81	·82
December	1·00	1·04	1·00	·94	·93	·92	·90	·87	·85	·82	·83
	1·000	1·023	·989	·959	·949	·943	·936	·914	·901	·904	·871
1867.											
January	1·00	1·06	·99	·96	·91	·90	·87	·86	·83	·82	·78
February	1·00	1·03	·99	·93	·88	·89	·87	·83	·80	·77	·77
March	1·00	1·22	1·11	·99	·93	·91	·91	·91	·88	·79	·94
April	1·00	1·00	1·00	·97	·96	·95	·94	·92	·89	·88	·86
May	1·00	·99	·99	·98	·98	·97	·97	·96	·96	·95	·90
June	1·00	1·00	1·00	·98	·97	·97	·97	·97	·95	·94	·89
July	1·00	·98	·99	·97	·97	·97	·97	·96	·95	·95	·90
August	1·00	·99	·99	·97	·98	·97	·97	·97	·96	·96	·94
September	1·00	·98	1·00	·98	·97	·97	·97	·96	·95	·93	·89
October	1·00	1·00	1·00	·99	·99	·98	·97	·96	·95	·94	·92
November	1·00	·99	·96	·95	·96	·95	·94	·92	·91	·90	·85
December	1·00	1·02	1·02	·96	·92	·90	·87	·86	·85	·85	·83
	1·000	1·022	1·004	·969	·952	·944	·935	·923	·907	·890	·873

TABLE IV.—Amount collected in each gauge yearly, 1863–67, Castle House, Calne, Wilts.

	Elevation Series. 8 inches diameter.										
	Isolated level.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-inch gauge.
	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
Part of 1863..	......	13·334	13·291	13·065	12·891	12·784	12·635	12·509	12·343	12·297	11·798
1864..	......	21·645	21·338	21·040	20·687	20·316	20·086	19·838	19·544	19·166	18·548
1865..	......	32·289	31·971	30·755	30·426	29·805	29·877	29·449	28·905	28·879	28·091
1866..	35·924	36·804	35·745	34·501	34·043	33·790	33·556	32·735	32·266	32·357	31·597
1867..	31·569	32·512	31·764	30·630	30·074	29·791	29·503	29·187	28·596	27·986	27·599
Total 1863–67	......	136·584	134·109	129·991	128·121	126·486	125·657	123·718	121·654	120·685	117·633

Ratio of the values in Table IV. to that at 1 foot.

Date.	Isolated level.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-inch gauge.
Part of 1863 ...	......	1·035	1·031	1·014	1·000	·992	·980	·971	·958	·955	·916
1864 ...	......	1·046	1·032	1·017	1·000	·983	·971	·960	·946	·926	·897
1865 ...	......	1·061	1·051	1·012	1·000	·980	·982	·968	·951	·949	·923
1866 ...	1·055	1·082	1·050	1·013	1·000	·993	·986	·962	·947	·950	·928
1867 ...	1·050	1·081	1·056	1·018	1·000	·990	·981	·970	·951	·930	·918
Total	......	1·067	1·047	1·015	1·000	·988	·982	·966	·950	·943	·919
Ratio of the values in Table IV. to the pit gauge.											
1866.........	1·000	1·025	·995	·961	·948	·941	·935	·912	·898	·901	·880
1867.........	1·000	1·031	1·007	·970	·952	·944	·935	·924	·906	·887	·875
Mean	1·000	1·028	1·001	·966	·950	·943	·935	·918	·902	·894	·878

TABLE V.—One-foot Ratios, grouped according to months.

Elevation Series. 8 inches diameter.											
Date.	Isolated level.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-in. gauge
1864, January ...	...	1·08	1·08	1·03	1·00	·97	·96	·94	·92	·91	·90
1865, " ...	...	1·11	1·10	1·02	1·00	·90	·92	·91	·87	·90	·89
1866, " ...	1·17	1·26	1·19	1·08	1·00	·99	1·01	·95	·92	·94	·92
1867, " ...	1·09	1·16	1·08	1·05	1·00	·98	·95	·94	·91	·89	·85
Mean	...	1·152	1·113	1·045	1·000	·960	·960	·935	·905	·910	·890
1864, February ...	...	1·11	1·08	1·07	1·00	·99	·97	·95	·92	·91	·87
1865, " ...	...	1·19	1·20	1·03	1·00	·97	·96	·96	·90	·91	·87
1866, " ...	1·05	1·09	1·06	1·03	1·00	·99	·97	·93	·93	·92	·90
1867, " ...	1·13	1·17	1·12	1·05	1·00	1·01	·98	·94	·90	·87	·88
Mean	...	1·140	1·115	1·045	1·000	·990	·970	·945	·912	·903	·880
1864, March	...	1·06	1·06	1·02	1·00	·98	·97	·94	·95	·95	·92
1865, "	...	1·12	1·08	1·02	1·00	·97	·97	·95	·93	·94	·90
1866, "	1·06	1·06	1·05	1·02	1·00	·99	·95	·92	·94	·97	·91
1867, "	1·08	1·32	1·20	1·07	1·00	·98	·98	·98	·95	·85	1·01
Mean	...	1·140	1·098	1·033	1·000	·980	·968	·948	·943	·928	·935
1864, April	...	1·03	1·02	1·00	1·00	·99	·98	·97	·96	·95	·93
1865, "	1·02	1·07	1·05	1·01	1·00	·99	·99	·97	·97	·95	·90
1866, "	1·06	1·08	1·05	1·02	1·00	1·00	·99	·96	·97	·97	·93
1867, "	1·04	1·04	1·03	1·00	1·00	·99	·98	·95	·92	·91	·89
Mean	...	1·055	1·038	1·008	1·000	·993	·985	·963	·955	·945	·913
1864, May	...	1·03	1·03	1·04	1·00	·99	·98	·97	·96	·95	·92
1865, "	1·03	1·05	1·02	1·00	1·00	1·00	1·00	·98	·96	·96	·92
1866, "	1·05	1·07	1·04	1·00	1·00	1·00	1·00	·98	·96	·96	·88
1867, "	1·02	1·01	1·02	1·00	1·00	·99	·99	·99	·98	·97	·92
Mean	...	1·040	1·028	1·010	1·000	·995	·993	·980	·965	·960	·910
1864, June.........	...	1·04	1·02	1·02	1·00	·98	·97	·96	·95	·93	·88
1865, "	1·01	1·01	1·00	1·00	1·00	1·00	1·00	·99	·98	·97	·93
1866, "	1·02	1·03	1·01	·99	1·00	1·00	1·00	·98	·97	·97	·95
1867, "	1·03	1·03	1·02	1·01	1·00	1·00	·99	1·00	·97	·97	·91
Mean	...	1·028	1·013	1·005	1·000	·995	·990	·983	·968	·960	·918
1864, July.........	...	·99	1·00	·99	1·00	·98	·98	·95	·95	·90	·86
1865, "	1·04	1·03	1·03	1·01	1·00	1·00	1·00	·99	·98	·94	·96
1866, "	1·03	1·04	1·02	·99	1·00	1·00	1·00	1·00	·96	·97	·96
1867, "	1·03	1·00	1·01	1·00	1·00	1·00	1·00	·99	·98	·98	·92
Mean	...	1·015	1·015	·998	1·000	·995	·995	·983	·968	·948	·925
1863, August......	...	1·02	1·02	1·00	1·00	1·00	·99	·98	·97	·96	·93
1864, "	...	1·03	1·02	·99	1·00	·98	·97	·95	·94	·92	·86
1865, "	1·02	1·02	1·01	1·00	1·00	1·00	1·00	·99	·99	·97	·95
1866, "	1·03	1·04	1·02	·99	1·00	·99	·99	·99	·98	·98	·95
1867, "	1·02	1·01	1·01	·99	1·00	·99	·99	·99	·98	·98	·95
Mean	...	1·024	1·016	·994	1·000	·992	·988	·980	·972	·962	·928

TABLE V. (*continued*).

Elevation Series. 8 inches diameter.

Date.	Isolated level.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-in. gauge
1863, September	...	1·00	1·00	1·00	1·00	1·00	·98	·98	·97	·94	·92
1864, "	...	1·04	1·00	1·02	1·00	·99	·97	·96	·94	·91	·87
1865, "	·98	1·00	1·00	·94	1·00	1·07	1·18	1·11	1·18	1·12	·83
1866, "	1·03	1·03	1·02	1·00	1·00	1·00	1·00	·98	·98	·98	·97
1867, "	1·03	1·01	1·03	1·00	1·00	1·00	·99	·99	·98	·96	·91
Mean	...	1·016	1·010	·992	1·000	1·012	1·024	1·004	1·010	·982	·900
1863, October ...	...	1·03	1·02	1·01	1·00	·99	·98	·97	·96	·96	·93
1864, " ...	...	1·02	1·01	1·00	1·00	·98	·98	·97	·96	·92	·91
1865, " ...	1·01	1·01	1·01	1·00	1·00	1·00	·99	·98	·98	·98	·95
1866, " ...	1·03	1·03	1·01	1·00	1·00	1·00	·99	·99	·98	·98	·93
1867, " ...	1·01	1·02	1·01	1·00	1·00	·99	·98	·97	·96	·95	·93
Mean	...	1·022	1·012	1·002	1·000	·992	·984	·976	·968	·958	·930
1863, November	...	1·09	1·08	1·03	1·00	·98	·97	·96	·94	·96	·90
1864, "	...	1·06	1·05	1·01	1·00	·98	·97	·96	·93	·91	·89
1865, "	1·03	1·05	1·04	1·01	1·00	·98	·98	·96	·94	·94	·92
1866, "	1·06	1·08	1·04	1·00	1·00	·97	·96	·92	·88	·85	·87
1867, "	1·05	1·04	1·01	1·00	1·00	1·00	·99	·96	·96	·94	·89
Mean	...	1·064	1·044	1·010	1·000	·982	·974	·952	·930	·920	·894
1863, December...	...	1·08	1·08	1·06	1·00	·97	·95	·94	·92	·91	·84
1864, " ...	...	1·04	1·03	1·01	1·00	·98	·96	·97	·95	·93	·90
1865, " ...	1·02	1·09	1·06	1·03	1·00	·97	·97	·95	·93	·95	·91
1866, " ...	1·08	1·12	1·07	1·01	1·00	·99	·97	·94	·91	·88	·90
1867, " ...	1·08	1·10	1·10	1·04	1·00	·97	·95	·93	·92	·92	·90
Mean	...	1·086	1·068	1·030	1·000	·975	·960	·946	·926	·918	·890

TABLE VI.—Mean Monthly Values deduced from Table V.

(Abstract.)

Date.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-in. gauge.
January	1·152	1·113	1·045	1·000	·960	·960	·935	·905	·910	·890
February ...	1·140	1·115	1·045	1·000	·990	·970	·945	·912	·903	·880
March.........	1·140	1·098	1·033	1·000	·980	·968	·948	·943	·928	·935
April	1·055	1·038	1·008	1·000	·993	·985	·963	·955	·945	·913
May	1·040	1·028	1·010	1·000	·995	·993	·980	·965	·960	·910
June	1·028	1·013	1·005	1·000	·995	·990	·983	·968	·960	·918
July	1·015	1·015	·998	1·000	·995	·995	·983	·968	·948	·925
August	1·024	1·016	·994	1·000	·992	·988	·980	·972	·962	·928
September ...	1·016	1·010	·992	1·000	1·012	1·024	1·004	1·010	·982	·900
October	1·022	1·012	1·002	1·000	·992	·984	·976	·968	·958	·930
November ...	1·064	1·044	1·010	1·000	·982	·974	·952	·930	·920	·894
December ...	1·086	1·068	1·030	1·000	·976	·960	·935	·905	·910	·890
	1·065	1·048	1·014	1·000	·989	·983	·965	·950	·941	·909

TABLE VII.—Mean Monthly Ratios (from Table III.), pit gauge=1·000.

Elevation Series. 8 inches diameter.											
Date.	Isolated level.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-in. gauge.
January	1·000	1·070	1·000	·940	·885	·875	·865	·835	810	·810	·785
February ...	1·000	1·035	1·000	·955	·915	·915	·900	·860	·840	·825	·810
March.........	1·000	1·115	1·030	·980	·940	·925	·905	·890	·885	·855	·900
April	1·000	1·023	1·003	·973	·960	·953	·947	·927	·920	·910	·870
May	1·000	1·010	·990	·967	·967	·963	·963	·947	·937	·930	·880
June	1·000	1·003	·993	·980	·980	·980	·980	·967	·957	·950	·913
July	1·000	·997	·990	·967	·967	·973	·970	·963	·943	·940	·903
August	1·000	1·000	·990	·970	·977	·970	·970	·967	·957	·957	·930
September ...	1·000	·995	·995	·980	·970	·970	·970	·960	·950	·945	·920
October	1·000	1·000	·993	·983	·983	·977	·973	·963	·957	·953	·923
November ...	1·000	1·010	·980	·960	·960	·940	·933	·910	·883	·873	·853
December ...	1·000	1·043	1·020	·973	·943	·927	·907	·890	·870	·867	·853
	1·000	1·025	·999	·969	·954	·947	·940	·923	9·09	·901	·878

TABLE VIII.—Monthly Ratios, 1864–65, grouped according to *mean temperature.*

Elevation Series. 8 inches diameter.											
Mean temperature on days with rain.	Date.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-inch gauge
38·5°	Jan. 1865 ...	1·11	1·10	1·02	1·00	·90	·92	·91	·87	·90	·89
39·6	Mar. „ ...	1·12	1·08	1·02	1·00	·97	·97	·95	·93	·94	·90
41·1	Feb. „ ...	1·19	1·20	1·03	1·00	·97	·96	·96	·90	·91	·87
41·7	Mar. 1864 ...	1·06	1·06	1·02	1·00	·98	·97	·94	·95	·95	·92
43·3	Feb. „ ...	1·11	1·08	1·07	1·00	·99	·97	·95	·92	·91	·87
43·9	Jan. „ ...	1·08	1·08	1·03	1·00	·97	·96	·94	·92	·91	·90
41·3		1·112	1·100	1·032	1·000	·963	·958	·942	·915	·920	·892
44·7	Nov. 1865 ...	1·05	1·04	1·01	1·00	·98	·98	·96	·94	·94	.92
44·7	Dec. 1864 ...	1·04	1·03	1·01	1·00	·98	·96	·97	·95	·93	·90
45·4	Apr. „ ...	1·03	1·02	1·00	1·00	·99	·98	·97	·96	·95	·93
46·3	Nov. „ ...	1·06	1·05	1·01	1·00	·98	·97	·96	·93	·91	·89
50·6	Oct. 1865 ...	1·01	1·01	1·00	1·00	1·00	·99	·98	·98	·98	·95
52·2	„ 1864 ...	1·02	1·01	1·00	1·00	·98	·98	·97	·96	·92	·91
47·3		1·033	1·027	1·005	1·000	·985	·977	·968	·953	·938	·916
52·3	Apr. 1865 ...	1·07	1·05	1·01	1·00	·99	·99	·97	·97	·95	·90
52·8	May „ ...	1·05	1·02	1·00	1·00	1·00	1·00	·98	·96	·96	·92
55·0	„ 1864 ...	1·03	1·03	1·04	1·00	·99	·98	·97	·96	·95	·92
57·1	June 1865 ...	1·01	1·00	1·00	1·00	1·00	1·00	·99	·98	·97	·93
57·4	„ 1864 ...	1·04	1·02	1·02	1·00	·98	·97	·96	·95	·93	·88
57·7	Sept. „ ...	1·04	1·00	1·02	1·00	·99	·97	·96	·94	·91	·87
55·4		1·040	1·020	1·015	1·000	·992	·985	·972	·960	·945	·903
58·4	Aug. 1864 ...	1·03	1·02	·99	1·00	·98	·97	·95	·94	·92	·86
58·4	„ 1865 ...	1·02	1·01	1·00	1·00	1·00	1·00	·99	·99	·97	·95
61·2	July 1864 ...	·99	1·00	·99	1·00	·98	·98	·95	·95	·90	·86
61·2	„ 1865 ...	1·03	1·03	1·01	1·00	1·00	1·00	·99	·98	·94	·96
62·8	Sept. „ ...	1·00	1·00	·94	1·00	1·07	1·18	1·11	1·18	1·12	·83
60·4		1·014	1·012	·986	1·000	1·006	1·026	·998	1·008	·970	·892

TABLE IX.—Monthly Ratios, 1864-65, grouped according to *Mean Humidity.*

Mean Humidity on days with rain.	Date.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-in. gauge
	Elevation Series. 8 inches diameter.										
(Sat.=100)											
63·6	Aug. 1864	1·03	1·02	·99	1·00	·98	·97	·95	·94	·92	·86
67·9	July „	·99	1·00	·99	1·00	·98	·98	·95	·95	·90	·86
69·3	June „	1·04	1·02	1·02	1·00	·98	·97	·96	·95	·93	·88
71·5	Aug. 1865	1·02	1·01	1·00	1·00	1·00	1·00	·99	·99	·97	·95
71·8	Sept. 1864	1·04	1·00	1·02	1·00	·99	·97	·96	·94	·91	·87
72·5	May „	1·03	1·03	1·04	1·00	·99	·98	·97	·96	·95	·92
69·4		1·025	1·013	1·010	1·000	·987	·978	·963	·955	·930	·890
73·2	July 1865	1·03	1·03	1·01	1·00	1·00	1·00	·99	·98	·94	·96
73·9	May „	1·05	1·02	1·00	1·00	1·00	1·00	·98	·96	·96	·92
74·2	Sept. „	1·00	1·00	·94	1·00	1·07	1·18	1·11	1·18	1·12	·83
77·5	Mar. „	1·12	1·08	1·02	1·00	·97	·97	·95	·93	·94	·90
79·9	„ 1864	1·06	1·06	1·02	1·00	·98	·97	·94	·95	·95	·92
80·5	Apr. 1865	1·07	1·05	1·01	1·00	·99	·99	·97	·97	·95	·90
76·5		1·055	1·040	1·000	1·000	1·002	1·018	·990	·995	·977	·905
80·7	Oct. 1865	1·01	1·01	1·00	1·00	1·00	·99	·98	·98	·98	·95
81·7	Feb. 1864	1·11	1·08	1·07	1·00	·99	·97	·95	·92	·91	·87
81·9	April „	1·03	1·02	1·00	1·00	·99	·98	·97	·96	·95	·93
83·7	Nov. 1865	1·05	1·04	1·01	1·00	·98	·98	·96	·94	·94	·92
84·1	Oct. 1864	1·02	1·01	1·00	1·00	·98	·98	·97	·96	·92	·91
85·5	Feb. 1865	1·19	1·20	1·03	1·00	·97	·96	·96	·90	·91	·87
82·9		1·075	1·060	1·018	1·000	·985	·977	·965	·943	·935	·908
85·6	Nov. 1864	1·06	1·05	1·01	1·00	·98	·97	·96	·93	·91	·89
89·1	Jan. 1865	1·11	1·10	1·02	1·00	·90	·92	·91	·87	·90	·89
89·6	„ 1864	1·08	1·08	1·03	1·00	·97	·96	·94	·92	·91	·90
90·6	June 1865	1·01	1·00	1·00	1·00	1·00	1·00	·99	·98	·97	·93
93·6	Dec. 1864	1·04	1·03	1·01	1·00	·98	·96	·97	·95	·93	·90
89·7		1·060	1·052	1·014	1·000	·966	·962	·954	·930	·924	·902

TABLE X.—Monthly Ratios, 1864–65, grouped according to *Velocity of Wind.*

Elevation Series. 8 inches diameter.											
Mean daily Horizontal motion of air on days with rain.	Date.	Level.	ft. in. 0 2	ft. in. 0 6	ft. in. 1 0	ft. in. 2 0	ft. in. 3 0	ft. in. 5 0	ft. in. 10 0	ft. in. 20 0	ft. in. 20 0 5-in. gauge.
miles.											
167·4	January 1865	1·11	1·10	1·02	1·00	·90	·92	·91	·87	·90	·89
151·0	November 1864 ...	1·06	1·05	1·01	1·00	·98	·97	·96	·93	·91	·89
149·6	December 1865 ...	1·09	1·06	1·03	1·00	·97	·97	·95	·93	·95	·91
147·0	March 1865	1·12	1·08	1·02	1·00	·97	·97	·95	·93	·94	·90
135·5	February 1864 ...	1·11	1·08	1·07	1.00	·99	·97	·95	·92	·91	·87
128·6	March 1864	1·06	1·06	1·02	1·00	·98	·97	·94	·95	·95	·92
146·5		1·092	1·072	1·028	1·000	·965	·962	·943	·922	·927	·897
126·0	November 1865 ...	1·05	1·04	1·01	1·00	·98	·98	·96	·94	·94	·92
121·0	February 1865 ...	1·19	1·20	1·03	1·00	·97	·96	·96	·90	·91	·87
118·0	January 1864	1·08	1·08	1·03	1·00	·97	·96	·94	·92	·91	·90
117·8	December 1864 ...	1·04	1·03	1·01	1·00	·98	·96	·97	·95	·93	·90
109·6	April 1864	1·03	1·02	1·00	1·00	·99	·98	·97	·96	·95	·93
100·9	October 1864	1·02	1·01	1·00	1·00	·98	·98	·97	·96	·92	·91
115·6		1·068	1·063	1·013	1·000	·978	·970	·962	·938	·927	·905
100·0	August 1865	1·02	1·01	1·00	1·00	1·00	1·00	·99	·99	·97	·95
97·0	July 1865	1·03	1·03	1·01	1·00	1·00	1·00	·99	·98	·94	·96
95·8	June 1864	1·04	1·02	1·02	1·00	·98	·97	·96	·95	·93	·88
95·0	May 1864	1·03	1·03	1·04	1·00	·99	·98	·97	·96	·95	·92
94·3	April 1865	1·07	1·05	1·01	1·00	·99	·99	·97	·97	·95	·90
88·8	June 1865	1·01	1·00	1·00	1·00	1·00	1·00	·99	·98	·97	·93
95·2		1·033	1·023	1·013	1·000	·993	·990	·978	·972	·952	·923
85·7	May 1865	1·05	1·02	1·00	1·00	1·00	1·00	·98	·96	·96	·92
83·4	October 1865	1·01	1·01	1·00	1·00	1·00	·99	·98	·98	·98	·95
82·6	September 1864 ...	1·04	1·00	1·02	1·00	·99	·97	·96	·94	·91	·87
81·7	July 1864	·99	1·00	·99	1·00	·98	·98	·95	·95	·90	·86
76·5	August 1864	1·03	1·02	·99	1·00	·98	·97	·95	·94	·92	·86
58·0	September 1865 ...	1·00	1·00	1·94	1·00	1·07	1·18	1·11	1·18	1·12	·83
78·0		1·020	1·008	·990	1·000	1·003	1·015	·988	·992	·965	·882

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground. ft.	in.	Above sea-level. feet.
321.	1869. July 8.	BERKSHIRE. Englefield House, Reading *R. BENYON, ESQ., M.P.* *Mr. E. Robinson.*	XI.	Negretti & Zambra	9 a.m.	1	0	190
322.	July 8.	BERKSHIRE. Englefield House, Reading. *R. BENYON, ESQ., M.P.* *Mr. E. Robinson.*	X.	Anon	9 a.m.	2	6	190
323.	Aug. 26.	DEVON. Manston Terrace, Exeter. *MISS DYMOND.* *Miss Dymond.*	III.	Anon	9 a.m.	0	1	165
324.	Aug. 26.	DEVON. The Field, Parker's Well, Exeter. *THE. REV. H. A. BOX.* *The Rev. H. A. Box.*	X.	Negretti & Zambra	9 a.m.	0	6	9[illegible]
325.	Aug. 26.	DEVON. Parker's Well. The Garden. *THE REV. H. A. BOX.* *The Rev. H. A. Box.*	X.	Negretti & Zambra	9 a.m.	0	6	9[illegible]
326.	Aug. 27.	DEVON. Clyst St. George, Topsham. *THE REV. H. T. ELLACOMBE.* *The Rev. H. T. Ellacombe.*	III.	Casella	9 a.m.	1	3	7[illegible]
327.	Aug. 27.	DEVON. Ash Villa, Budleigh Salterton. *R. WALKER, ESQ., M.D.* *R. Walker, Esq., M.D.*	XII.	Casella	9 a.m.	4	0	3[illegible]
328.	Aug. 28.	DEVON. Brampford Speke, Exeter. *W. H. GAMLEN, ESQ.* *W. H. Gamlen, Esq.*	XII.	Apps	9 a.m.	1	0	14[illegible]
329.	Aug. 28.	DEVON. Brampford Speke, Exeter. *W. H. GAMLEN, ESQ.* *W. H. Gamlen, Esq.*	X.	Local	monthly.	0	3	14[illegible]
330.	Aug. 28.	DEVON. High Street, Exeter. *W. H. ELLIS, ESQ.*	III. But the funnel alone is outside.	Negretti & Zambra	9 a.m.	47	11	18[illegible]
331.	Aug. 28.	DEVON. High Street, Exeter. *W. H. ELLIS, ESQ.*	As 330 but not on post.	....	....	44	3	18[illegible]

RAIN-GAUGES (*continued from last Report*).

Diameters (that marked M = mean).	Equivalents of water. Scale-point	Equivalents of water. Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
5·00	·1	500	−·001	S. Apple 42°.	On part of lawn; very fair position.	321.
5·02	·2	990	+·001	N. Vinery 20°.		
5·01	·3	1500	−·001			
5·00	·4	2000	−·002			
M 5·008	·5	2490	−·001			
8·05	·2	2650	−·006	....	Close to No. 321. Rather a rough gauge, mounted on a post.	322.
8·03	·3	3700	−·013			
8·05	·4	5090	−·005			
8·12						
M 8·063						
4·98	·1	500	−·001	W. House 48°.	This gauge was formerly at Albert Terrace, Exeter (see No. 86 for particulars). It is now on a lawn, and nearly level therewith. Is to be moved a few feet so as to lessen the angular elevation of the house. Rather round rim.	323.
5·02	·2	990	+·001	E. Shrubs 18°.		
5·02	·3	1460	+·005			
5·00	·5	2460	+·005			
M 5·005						
8·00	·1	1210	+·004	....	Quite clear in an open field, sloping slightly to S.E.	324.
8·00	·2	2500	+·003			
8·00	·3	3800	correct.			
7·98	·4	4980	+·007			
M 7·995	·5	6300	+·003			
7·93	·1	1250	+·001	W.S.W. Elms 38°	In garden near edge of lawn, and much nearer the house than No. 324. This gauge was formerly at Albert Terrace (see No. 84), but the funnel has been knocked about, and a new glass provided.	325.
8·02	·2	2540	correct.	N.W. House 31°.		
8·03	·3	3750	+·004			
8·00	·4	5000	+·006			
M 7·995	·5	6250	+·007			
5·00	·1	495	correct.	S.W. Trees 32°.	Gauge enclosed in a square box, placed in a level garden N. of the church.	326.
4·99	·2	990	correct.			
5·00	·3	1470	+·003			
5·01	·4	1960	+·005			
M 5·000	·5	2480	correct.			
4·98	·1	500	−·001	N. House 60°.	Very bad position, but no better obtainable. Gauge mounted in an ornamental vase in small front garden.	327.
5·01	·2	990	correct.	S. Trees 30°.		
5·01	·3	1480	+·001	S.W. ,, 30°.		
5·00	·4	2000	−·003			
M 5·000	·5	2480	correct.			
5·06	·1	500	+·001	W. House 25°.	On lawn in front of house; very good position.	328.
5·04	·2	1000	+·002			
5·05	·3	1490	+·005			
5·02	·4	2000	+·004			
M 5·043	·5	2510	+·002			
8·00	·1	1280	−·001	....	Close to No. 328.	329.
8·10	·2	2545	+·002			
8·00	·32	3980	+·011			
8·12						
M 8·055						
5·02	·1	500	correct.	....	On post on roof of observatory above all surrounding objects. About 6 ft. of piping leads the water into a receptacle inside the observatory.	330.
5·02	·2	980	+·004			
5·01	·3	1500	correct.			
5·03	·4	1985	+·003			
M 5·020	·5	2525	−·005			
10·00	·1	1900	+·004	....	Near No. 330, but not affected thereby; about 1 ft. of tubing is used with this gauge. (See previous examination, No. 87.)	331.
10·00	·2	3850	+·006			
10·02	·3	5940	+·001			
10·00	·4	7940	correct.			
M 10·005	·5	9780	+·007			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. STATION. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Above sea-level.
	1869.					ft. in.	feet.
332.	Aug. 28.	DEVON. Exeter Institution. *THE INSTITUTION.* *Mr. Parfitt.*	II.	....	9 a.m.	13 7	155
333.	Aug. 30.	DEVON. Landscore, Teignmouth. *MRS. CLARKE.* *Mrs. Clarke.*	III.	Local	9 a.m.	0 3	125
334.	Aug. 31.	DEVON. Chagford, Moreton Hampstead. *R. L. BERRY, ESQ.* *R. L. Berry, Esq.*	III.	Private	monthly.	0 7	575
335.	Aug. 31.	DEVON. Bishopsteignton. *THE REV. S. M. SCROGGS.* *The Rev. S. M. Scroggs.*	III.	Elliot	9 a.m.	6 0	120
336.	Sept. 1.	DEVON. Druid House, Ashburton. *F. AMERY, ESQ.* *F. Amery, Esq.*	....	Private	9 a.m.	Level.	570
337.	Sept. 1.	DEVON. Middlecote House, Ilsington. *A. LYON, ESQ.* *A. Lyon, Esq.*	VIII.	Casartelli	....	3 6	639
338.	Sept. 2.	DEVON. Rose Hill Cottage, Newton Bushell. *MRS. HARRIS.* *Mrs. Harris.*	III.	Funnel, Anon. Glass, Pastorelli.	9 a.m.	1 0	64
339.	Sept. 2.	DEVON. Lamorna, Torquay. *BRITISH ASSOCIATION.* *W. Pengelly, Esq., F.R.S.*	III	Casella	9 a.m.	0 9	205
340.	Sept. 2.	DEVON. Lupton, Brixham. *Mr. G. Erskine.*	IV	....	....	3 0	200
341.	Sept. 3.	DEVON. Fore Street, Kingsbridge. *G. FOX.* *G. Fox.*	III	Glass, Casella. Funnel, Private.	....	0 6	68

RAIN-GAUGES (*continued*).

Diameters (that marked M = mean).	Equivalents of water. Scale-point.	Equivalents of water. Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
6·18	....	....	....	....	Previously examined in 1863 (see No. 88). This gauge is getting past work, and if the record is to be continued, a new one is required.	332.
6·13						
6·12						
M 6·143						
5·05	·1	500	correct.	....	On lawn, in the best position the grounds afford.	333.
5·03	·2	980	+·004			
5·02	·3	1500	correct.			
5·00	·4	2000	+·001			
M 5·025	·5	2500	+·001			
4·98	·1	400	+·019	N.W. Tree 52°.	Observer said he knew his gauge was wrong, and divided by 1·16, which brought it right, but it does not; *e. g.* ·5 ÷ 1·16 = ·431 = 2128 grs.; but the glass holds only 1960, therefore there is still an error of ·034. A new and correct glass has been substituted.	334.
4·98	·2	780	+·042			
5·01	·3	1135	+·070			
4·99	·4	1500	+·096			
M 4·990	·5	1960	+·103			
	·6	2380	+·118			
	·7	2750	+·143			
5·03	·1	500	+·001	....	On a post in kitchen garden; if nearer ground it would be sheltered by trees and shrubs; a few hundred yards W. of the church.	335.
5·05	·2	1020	−·002			
5·03	·3	1500	+·002			
5·05	·4	2000	+·003			
M 5·040	·5	2500	+·004			
2·60	·2	234	+·018	....	A privately constructed gauge placed close to a shelving bank. A new gauge has since been placed on level ground.	336.
2·50	·5	580	+·048			
2·55	1·0	1200	+·066			
2·55	1·5	1800	+·098			
M 2·550						
8·40	·10	1445	−·001	N. House 28°.	Near a hedge which was about 10° above the gauge; observer said he had intended to have it clipped, and it should be done at once.	337.
8·55	·18	2600	−·002			
8·50	·39	5600	−·002			
8·50						
M 8·488						
5·05	·1	500	+·001	....	In garden but not at work; observations to be resumed forthwith.	338.
5·05	·2	970	+·009			
5·08	·3	1480	+·008			
5·05	·4	2000	+·006			
M 5·058	·5	2480	+·011			
5·00	·1	500	−·001	S. Trees 48°.	On lawn, in best position possible.	339.
5·00	·2	990	correct.	S.E. Trees 45°.		
5·01	·3	1490	correct.			
4·99	·4	1980	+·001			
M 5·000	·5	2480	correct.			
12·05	·1	2870	correct.	S.E. Pear 32°.	In gardens very well placed.	340.
11·98	·3	8580	correct.			
12·01	·5	14780	−·017			
12·00						
M 12·010						
5·00	·1	500	−·001	S.W. Laburn. 70°.	Very flat rim; position obviously very bad. Recommended that this gauge should remain in its position till the end of the year.	341.
5·00	·2	970	+·004	N. House 52°.		
5·00	·3	1480	+·001			
5·00	·4	1970	+·003			
M 5·000	·5	2460	+·004			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.		Above sea-level.
	1869.					ft.	in.	feet.
342.	Sept. 3.	DEVON. Fore Street, Kingsbridge. *G. FOX.* *G. Fox.*	III	....	....	0	6	68
343.	Sept. .	DEVON. Burton, Kingsbridge. *W. BALKWILL, ESQ.* *W. Balkwill, Esq.*	XII	Burrow	weekly & 1st of month.	5	6	200
344.	Sept. 3.	DEVON. Bolt Tail, Kingsbridge. *W. BALKWILL, ESQ.* *W. Balkwill, Esq.*	III	....	....	1	0	297
345.	Sept. 6.	DEVON. Prison Reservoir, Dartmoor. *MR. WATTS.* *Mr. Watts.*	III	Casella	9 a.m.	0	2	1400
346.	Sept. 6.	DEVON. North Hessary Tor, Dartmoor. *MR. WATTS.* *Mr. Watts.*	VIII	....	....	0	6	1596
347.	Sept. 7.	DEVON. Powder Mills, Dartmoor. *BRITISH ASSOCIATION.* *Mr. Henwood.*	XII	Casella	9 a.m.	1	0	1200
348.	Sept. 8.	DEVON. Mount Tavy, Tavistock. *MISS CARPENTER.*	III	Casella	....	1	0	316
349.	Sept. 8.	DEVON. West Street, Tavistock. *T. WINDEATT, ESQ.* *T. Windeatt, Esq.*	....	Anon	monthly.	4	6	236
350.	Sept. 8.	DEVON. Old Town Street, Plymouth. *A. P. BALKWILL, ESQ.* *A. P. Balkwill, Esq.*	III Funnel outside roof, bottle inside	Anon	weekly.	35	0	150
351.	Sept. 9.	CORNWALL. Port Eliot, St. Germans. *RT. HON. EARL ST. GERMANS.* *Mr. Lynch.*	IV	Dixey	9 a.m.	4	0	81
352.	Sept. 10.	CORNWALL. Regent's Parade, Penzance. *W. H. RICHARDS, ESQ.* *W. H. Richards, Esq.*	IV	Negretti & Zambra	irregular & 1st of month.	3	0	94

RAIN-GAUGES (*continued*).

Diameters (that marked M = mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
	Scale-point.	Grains.				
in.	in.		in.			
4·96	....	....	....	....	Close to 342, but not in use. Recommended that it be moved to another and more open part of the garden and compared with No. 341.	342.
5·01						
4·98						
5·03						
M 4·995						
5·00	·1	500	−·001	....	Gauge stands about 1 foot above a bank running S. to N., and is fully exposed.	343.
5·03	·2	1000	−·002			
4·99	·3	1480	+·001			
4·98	·4	2000	−·004			
M 5·000	·5	2490	−·002			
5·03	·1	490	+·003	....	Gauge in open moorland quite exposed, but concealed from view by loose stones, among which it is placed.	344.
5·02	·2	980	+·004			
5·05	·3	1460	+·010			
5·07	·4	1970	+·010			
M 5·042	·5	2440	+·016			
5·00	·1	500	−·001	N. Trees 20°.	Trees have grown considerably round this gauge since my former visit in 1863 (see No. 70). Mr. Watts promised to speak to the Governor on the subject.	345.
5·01	·2	1000	−·002	E.N.E. Trees 70°.		
5·01	·3	1480	+·002	S. Trees 72°.		
4·99	·47	2300	+·006			
M 5·002						
4·97	·1	500	−·001	....	New gauge in the same position as No. 71. Quite open.	346.
5·01	·2	1000	−·002			
4·98	·3	1480	+·001			
5·02	·47	2300	+·005			
M 4·995						
....	....	....	....	....	Gauge not erected at time of visit, but site was selected, where it will be very well situated and daily observations are promised.	347.
5·00	·1	500	−·001	N.N.E. Beech 58°.	In small garden S. of a small cottage by the side of the road to Dartmoor, about ¼ of a mile from Mount Tavy.	348.
5·00	·2	990	correct.	E. Trees 50°.		
5·00	·3	1490	correct.			
5·00	·4	1980	+·001			
M 5·000	·5	2470	+·002			
1·00 sq.	·1	25	+·002	....	A unique gauge 1 square inch in area, mounted on a post in a rather sheltered garden.	349.
1·00	1·0	250				
1·01	5·0	1250	+·120			
1·02	10·0	2510	+·200			
M 1·008						
5·00	·1	500	correct.	....	Gauge passes through, and its orifice is about 6 inches above the flat lead roof of a large warehouse; the bottle is supported by a small shelf beneath. Position very exposed.	350.
5·06	·2	990	+·003			
5·02	·3	1495	+·002			
5·03	·4	1975	+·006			
M 5·028	·5	2455	+·010			
12·23	·1	3000	−·005	N. Trees 55°.	Good position in the gardens.	351.
11·72	·2	5630	+·002			
12·10	·3	8610	−·003			
11·84	·4	11370	correct.			
M 11·973	·5	14280	−·002			
12·00	·1	3250	−·014	S.E. Workshop 25°.	In small grass enclosure, rather shut in by walls; however, nothing but the flagstaff rises 30°.	352.
11·93	·2	5810	−·004	S. Flagstaff 80°.		
12·00						
12·00						
M 11·983						

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground,		Above sea-level.
	1869.					ft.	in.	feet.
353.	Sept. 10.	CORNWALL. Penalverne, Penzance. *T. S. BOLITHO, ESQ.*	VII	Casella	....	0	6	150
354.	Sept. 11.	CORNWALL. Sawah, Penzance. *MR. J. SAUNDRY.* *Mr. J. Saundry.*	X	Whitley	....	4	0?	320?
355.	Sept. 11.	CORNWALL. St. Sennen, Land's End. *REV. G. L. WOOLLCOMBE.* *Rev. G. L. Woollcombe.*	III	Casella	weekly & 1st of month.	4	0	290?
356.	Sept. 13.	CORNWALL. St. Ruan Rectory, Helstone. *THE REV. F. C. JACKSON.* *The Rev. F. C. Jackson.*	II	Liddell	9 a.m.	2	8	110
357.	Sept. 13.	CORNWALL. Helstone. *M. P. MOYLE, ESQ.* *M. P. Moyle, Esq.*	III	Knight	....	5	0	115
358.	Sept. 13.	CORNWALL. Antron Lodge, Helstone. *THE REV. H. J. A. FOTHERGILL.* *The Rev. H. J. A. Fothergill.*	III	Anon	9 a.m.	6	0	235
359.	Sept. 13.	CORNWALL. Antron Lodge (Orchard). *THE REV. H. J. A. FOTHERGILL.* *The Rev. H. J. A. Fothergill.*	III	Anon	....	1	1	234
360.	Sept. 14.	CORNWALL. Penzance. *THE REV. PREBENDARY HEDGELAND.*	IV	Negretti & Zambra	9 a.m. preceding.	3	6	185
361.	Sept. 14.	CORNWALL. Penzance. *THE REV. PREBENDARY HEDGELAND.*	III	Whitley	not in use.	1	0	180
362.	Sept. 17.	CORNWALL. Tresco Abbey, Scilly Islands. *AUGUSTUS SMITH, ESQ.* *Mr. Hawkins.*	X	Whitley	9 a.m.	2	8	50
363.	Sept. 18.	CORNWALL. Parade, St. Mary's, Scilly Islands. *J. G. MOYLE, ESQ.* *J. G. Moyle, Esq.*	X	Whitley	....	1	0?	20

RAIN-GAUGES (*continued*).

Diameters (that marked M = mean).	Equivalents of water. Scale-point.	Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
10·00 sq.	....	....	....	....	On lawn, very good position, glass not accessible.	353.
10·00 ,,						
10·00 ,,						
10·00 ,,						
M 10·000						
M 11·3 ?	·10	2510	−·001	....	Altitude uncertain, barometer falling rapidly, and great gale blowing. Funnel lost and gauge dismantled.	354.
	·145	3580	−·002			
5·00	·1	500	+·001	....	Altitude uncertain; see above. Gauge partly sunk in a bank E. of the house, within a short distance of the Land's End.	355.
4·98	·2	1000	+·004			
5·02	·4	1980	+·007			
5·00	·5	2460				
M 5·000	1·0	4920				
8·20	·1–·2	1300	correct.	S. Trees 43°.	In garden, rather sheltered and below the level of the surrounding country.	356.
8·05	·2–·3	1270	+·003	W. House 30°.		
8·13	·3–·4	1310	−·001			
8·07	·4–·5	1230	+·006			
M 8·113	·5–·6	1270	+·003			
4·77	·2	970	+·005	....	In a garden sloping to S.E. so rapidly that though the gauge is on the ridge of an outhouse, it is only 5 ft. above the garden close to it. The funnel was loose, and much knocked about by (I suppose) having been often blown away.	357.
5·27	·3	1450	+·008			
4·85	·4	1940	+·009			
5·13	·5	2400	+·017			
M 5·005	·6	2910	+·014			
5·00	·1	450	+·011	....	Gauge in orchard, attached to a dwarf post.	358.
5·08	·2	880	+·025			
5·07	·3	1320	+·038			
5·00	·4	1750	+·053			
M 5·038						
5·00	·1	440	+·011	....	In field, near 358, clear of all objects. [*Note.*—I believe Mr. Fothergill makes some mental correction to the readings of his gauges, the nature of which I could not understand. Recommended to procure gauges of the ordinary construction.]	359.
5·00	·2	850	+·028			
4·97	·3	1300	+·036			
5·00	·4	1710	+·054			
M 4·993						
12·04	·1	2970	−·004	E. House 28°.	This and No. 361 had not been regularly observed for some time; fresh positions were selected for them, and observations will be recommenced forthwith.	360.
11·98	·45	13460	+·022	S. Trees 35°.		
11·90				W. ,, 32°.		
12·04						
M 11·990						
5·08	·0–·5	2650	−·021			361.
5·10	·5–1·0	2500	+·009			
5·03	1·0–1·5	2550	−·001			
5·05	1·5–2·0	2440	+·021			
M 5·065						
11·42	·1	2550	−·001	N.E. Bank 15°.	In gardens, very good position, but very flimsy and indifferent gauge.	362.
11·21	·25	6000	+·013			
11·30	·3	8000	−·015			
11·30						
M 11·308						
	·1	230	....	S. Gable end 30°.	Observations discontinued. Funnel lost. A new gauge has since been purchased by Mr. Moyle, and erected on the site of the old one in small garden in rear of house. No obstruction except as noted.	363.
	1·0	2500				
M 11·3?	1·3	3220				

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.		Above sea-level.
	1869.					ft.	in.	feet.
364.	Sept. 20.	CORNWALL. The Battery, Penzance. *METEOROLOG. COMMITTEE.* *Mr. Senior.*	X	Negretti & Zambra	8 a.m.	1	2	60
365.	Sept. 21.	CORNWALL. Tehidy Gardens, Redruth. *CAPT. BASSET.* *Mr. Mills.*	III	Anon	9 a.m. 1st of month.	0	4	160
366.	Sept. 21.	CORNWALL. Kimberley Place, Falmouth. *LOVEL SQUIRE, ESQ.* *Lovel Squire, Esq.*	III	Anon	10 a.m.	40	0	223
367.	Sept. 22.	CORNWALL. Coast-Guard House, New Quay. *MR. TREGIDGO.* *Mr. Tregidgo.*	II	Liddell	9 a.m.	1	9	90
368.	Sept. 23.	CORNWALL. Penarth, Truro. *N. WHITLEY, ESQ.* *N. Whitley, Esq.*	X	Whitley	9 a.m.	1	0	190
369.	Sept. 23.	CORNWALL. Royal Institution, Truro. *THE INSTITUTION.* *Mr. W. Newcombe.*	VII	....	9 a.m.	40	0	56
370.	Sept. 23.	CORNWALL. St. Agnes. *MR. J. OPIE.* *Mr. J. Opie.*	X	Whitley	....	1	0	278
371.	Sept. 23.	CORNWALL. Strangeway's Terrace, Truro. *C. BARHAM, ESQ., M.D.* *C. Barham, Esq., M.D.*	II	Liddell	9 a.m.	2	6	71
372.	Sept. 24	CORNWALL. Trevarna, St. Austell. *W. COODE, ESQ.* *W. Coode, Esq.*	III	Casella	9 a.m.	0	6	300
373.	Sept. 24.	CORNWALL. Castle Stret, Bodmin. *CAPT. LIDDELL, R.N.* *Capt. Liddell, R.N.*	II	Liddell	....	2	6	338
374.	Sept. 24.	CORNWALL. Castle Street, Bodmin. *CAPT. LIDDELL, R.N.* *Capt. Liddell, R.N.*	XII	....	....	0	1	338

RAIN-GAUGES (*continued*).

Diameters (that marked M = mean).	Equivalents of water. Scale-point.	Equivalents of water. Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
7·98	·1	1300	—·003	....	Standing on gravel in the battery of the Penzance Artillery Corps; an open position, but the gauge has to be moved whenever drill is going on.	364
7·95	·5	6380	—·008			
7·92						
7·98						
M 7·958						
5·04	·1	520	—·002	S.E. Beans 58°.	Gauge standing loosely on funnel, not level, and shut in on the south by rows of beans; the old observer had left, and the new gardener was not aware of the importance of accuracy.	365.
5·03	·42	2040	+·020	S.W. ,, 54°.		
5·10	1·13	5630	+·024			
5·09	1·60	8080	+·012			
M 5·065						
10·20 sq.	·05	1210	+·003	....	This gauge is a very old one inserted in the masonry of the new observatory tower built by the Meteorological Committee. It will not give even the rainfall on the tower correctly, as its rim is only an inch or two above the masonry, and therefore insplashing is inevitable.	366.
10·06	·09	2160	+·006			
10·00	·1	2510	+·003			
10·20						
M 10·115						
6·00	·1–·0	690	—·003	W. House 20°.	Very good position in the large garden of the station.	367.
6·00	·2–·1	680	—·005			
6·02	·3–·2	700	—·002			
6·00	·4–·3	730	+·002			
M 6·005	·5–·4	700	—·002			
11·30	·1	2550	correct.	S.W. Tree 52°.	Funnel fits loosely on can, and is prevented from being blown away by a large stone placed in it. Position not good, but no better available.	368.
11·27	·2	5150	—·003	N. House 48°.		
11·30	·3	7530	+·004			
11·41						
M 11·320						
10·10 sqr.	·1	2500	+·004	....	Funnel very old, had been previously repaired many times, but was coming to pieces; recommended that it should be repaired once more, and recorded simultaneously with a new gauge to be placed by its side on the roof.	369.
10·12	·2	5050	+·006			
10·34	·3	7480	+·013			
10·15						
M 10·178						
11·16	·10	2450	+·001	S.W. Trees 28°.	In garden, E.S.E. of St. Agnes' church; fair position, but very rough gauge. The measuring-glass had been broken, and mended with sealing-wax and a cork.	370.
11·15	·15	3655	+·002			
11·30						
11·06						
M 11·168						
8·05	·0–·1	1300	—·002	....	Good gauge, in good position.	371.
8·00	·1–·3	2530	+·001			
7·98	·3–·5	2580	—·003			
8·03	·5–·6	1300	—·002			
M 8·015	·6–·7	1320	—·004			
4·93	·1	495	correct.	N.W. Trees 38°.	Gauge not a true circle, but otherwise correct. Mr. Coode, however, decided on having a new one as a check.	372.
5·03	·2	990	—·001	S.W. ,, 27°.		
4·90	·3	1490	—·002			
5·08	·4	1970	correct.			
M 4·985	·5	2460	+·001			
8·05	·1	1230	+·004	W.N.W. Walnut 49°.	In garden, in rear of house, fair position, and the best obtainable.	373.
8·00	·2	2550	+·001	E.S.E. House 48°.		
8·04	·3	3710	+·010			
8·02	·5	6540	—·011			
M 8·028						
5·00	·1	500	correct.	....	Close to No. 373, upright rim, and zinc receiver.	374.
5·02	·2	1000	correct.			
5·04	·3	1500	correct.			
5·02	·4	2000	correct.			
M 5·020	·5	2500	correct.			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Height of gauge. Above sea-level.
						ft. in.	feet.
375.	1869. Sept. 24.	CORNWALL. Castle Street, Bodmin. *CAPT. LIDDELL, R.N.* *Capt. Liddell, R.N.*	III	Casella	....	1 0	338
376.	Sept. 24.	CORNWALL. Fore Street, Bodmin. *A. HAMBLY, ESQ.* *A. Hambly, Esq.*	II	Liddell	9 a.m.	2 6	336
377.	Sept. 25.	CORNWALL. Treharrock House. *F. B. HAMBLY, ESQ.* *F. B. Hambly, Esq.*	II	....	....	4 0	303
378.	Sept. 25.	CORNWALL. Treharrock House. *F. B. HAMBLY, ESQ.* *F. B. Hambly, Esq.*	XI	Negretti & Zambra	....	2 9	303
379.	Sept. 25.	CORNWALL. Park Villa, Endellion. *MISS GUY.* *Miss Guy.*	II	Liddell	....	3 0	277
380.	Sept. 25.	CORNWALL. Treglines, St. Minver. *MR. T. LIDDELL.* *Mr. T. Liddell.*	II	Liddell	....	3 0	140
381.	Sept. 25.	CORNWALL. Guinea Port, Wadebridge. *MR. JORDAN.* *Mr. Jordan.*	II	Liddell	8 a.m.	2 6	23
382.	Sept. 27.	CORNWALL. Warleggan, Bodmin. *THE REV. D. CLEMENTS.* *The Rev. D. Clements.*	II	Liddell	....	2 6	550
383.	Sept. 27.	CORNWALL. Trevalga Rectory, Boscastle. *THE REV. W. H. JAMES.* *The Rev. W. H. James.*	X	Negretti & Zambra	irregular.	0 6	540
384.	Sept. 28.	CORNWALL. Lanteglos Rectory, Camelford. *THE REV. J. T. WILKINSON.*	II	Skinner	....	2 6	403
385.	Sept. 28.	CORNWALL. Altarnum, Launceston. *C. U. TRIPP, ESQ.*	....	....	9 a.m.	0 10	570

RAIN-GAUGES (*continued*).

Diameters (that marked M=mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
	Scale-point.	Grains.				
in.	n.		in.			
5·02	·1	500	correct.	....	Close to No. 373.	375.
5·02	·2	1000	correct.			
5·00	·3	1500	−·001			
5·02	·4	2000	−·001			
M 5·015	·5	2500	−·001			
8·12	·1	1330	−·004	S.W. Tree 22°.	In garden, sloping to N. Rim of funnel very round, and difficult to measure.	376.
8·00	·2	2680	−·009			
8·04	·3	4130	−·022			
8·00	·4	5330	−·015			
M 8·040	·6	7880	−·014			
7·96	·1	1320	−·003	N. House 40°.	On lawn, ground undulating.	377.
8·15	·2	2590	−·001	W. Trees 32°.		
8·00	·3	3770	+·007			
8·10	·5	6330	+·008			
M 8·053						
5·00	....	....	....	N. House 33°.	Near No. 377, but further from the house; glass inaccessible.	378.
5·00						
5·01						
4·99						
M 5·000						
10·05 sqr.	·1	2550	+·001	N. House 35°.	This gauge was used at Roscarrock (about 2 miles hence) for several years. It is now well placed at corner of carriage drive.	379.
10·08	·2	5210	+·003			
10·10	·3	7630	+·002			
10·07	·4	10210	+·002			
M 10·075	·5	12810	correct.			
10·18 sqr.	·1	2625	−·002	E.N.E. House 32°.	On grass plot in centre of small quadrangle.	380.
10·15	·2	5085	+·003	S.S.E. „ 21°.		
10·05	·3	7620	+·005	W.S.W. „ 32°.		
10·10	·5	12550	+·015			
M 10·120						
8·25	·1	1300	+·001	S.W. House 40°.	In small front garden, close to terminus of the Wadebridge railway.	381.
7·99	·2	2600	+·001			
8·13	·3	3950	−·002			
8·12	·5	6890	−·027			
M 8·123						
8·00	·3–·2	1250	+·003	N. House 25°.	On lawn, capital position; round-edged funnel.	382.
8·15	·4–·3	1250	+·003			
7·94	·5–·4	1255	+·003			
8·10	·6–·5	1250	+·003			
M 8·048	·7–·6	1250	+·003			
8·05	·1	1270	correct.	....	In small enclosure, in slightly raised part of large field; capital situation.	383.
7·98	·2	2530	correct.			
8·05	·3	3760	+·002			
7·88	·4	5070	correct.			
M 7·990	·5	6280	+·004			
8·10	·1–·2	1310	−·001	N. House 42°.	Observer absent, gauge had been upset, and no observations taken; the float (a bung) was saturated and would not act; corrected it, and it read as per previous column.	384.
8·10	·2–·3	1300	correct.			
8·15	·3–·4	1290	+·001			
8·00	·4–·5	1310	−·001			
M 8·088	·5–·6	1300	correct.			
4·98	·1	490	+·001	N.W. House 30°.	In garden, near the church; good position.	385.
5·02	·2	975	+·003	S.E. Tree 25°.		
5·00	·3	1490	−·001			
4·99	·4	1990	−·002			
M 4·998	·5	2470	+·001			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of guage.	Maker's name.	Time of reading.	Height of gauge. Above ground.		Above sea-level.
						ft.	in.	feet.
386.	1869. Sept. 28.	CORNWALL. Hexworthy, Launceston. *H. M. HARVEY, ESQ.* *H. M. Harvey, Esq.*	XI	Negretti & Zambra	....	1	0	410
387.	Sept. 29.	CORNWALL. Coryton, Lew Down. *MR. T. SYMONS.* *Mr. T. Symons.*	IV	Carter, Exeter ...	8 a.m.	6	0	445
388.	Sept. 29.	DEVON. Sheepstor, Dartmoor. *PLYMOUTH WATER WORKS.* *Mr. Shillabeer.*	III	Anon	9 a.m.	0	10	693
389.	Sept. 30.	CORNWALL. White Rock, Hingston Down. *CAPT. RICHARDS.* *Capt. Richards.*	X	Whitley	9 a.m.	1	0	760
390.	Sept. 30.	CORNWALL. Church Street, Callington. *DR. KEMPTHORNE.* *Mr. Brown.*	III	Casella	9 a.m. preceding.	3	0	490
391.	Sept. 30.	CORNWALL. Pentillie Gardens, Saltash. *COL. CORYTON.* *Mr. Edwards.*	III	Casella	9 a.m. preceding.	1	3	162
392.	Sept. 30.	CORNWALL. Pentillie Castle, Saltash. *MISS CORYTON.* *Miss Coryton.*	III	Anon	....	1	6	....
393.	Oct. 1.	CORNWALL. Liskeard. *S. JENKIN, ESQ., C.E.* *S. Jenkin, Esq., C.E.*	XI	Negretti & Zambra	9 a.m.	1	1	375
394.	Oct. 1.	CORNWALL. Liskeard. *S. JENKIN, ESQ., C.E.* *S. Jenkin, Esq., C.E.*	II	Liddell	....	2	6	377
395.	Oct. 1.	CORNWALL. Catchfrench, St. Germans. *MISS GLANVILLE.* *Miss Glanville.*	X	Negretti & Zambra	10 a.m.	0	7	270
396.	Oct. 1.	DEVON. Gascoyne Place, Plymouth. *J. MERRIFIELD, ESQ., F.R.A.S.* *J. Merrifield, Esq., F.R.A.S.*	X	Negretti & Zambra	8 a.m.	26	6	100

RAIN-GAUGES (*continued*).

Diameters (that marked M=mean).	Equivalents of water. Scale-point.	Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
5·00	·1	498	correct.	W.S.W. Greenhouse 18°.	On lawn, very good position; glass broken, only 0·20 of it left.	386.
5·01	·2	990	+·001			
5·02						
5·00						
M 5·008						
12·00	·1–·2	2850	correct.	....	Very good gauge, very firmly fixed in an open garden.	387.
12·00	·2–·3	2845	correct.			
12·00	·3–·4	2845	correct.			
12·00	·4–·5	2840	+·001			
M 12·000	·5–·6	2890	−·001			
4·95	·1	490	+·001	S.W. Tree 40°.	In garden, in a valley about ½ mile N.W. of Sheepstor church.	388.
5·05	·2	980	+·002			
4·98	·3	1460	+·006			
5·03	·4	1990	−·001			
M 5·003	·5	2450	+·006			
11·23	·1	2530	correct.	....	In a garden, near the crest of the hill; exposed position.	389.
11·20	·2	5100	−·001			
11·38	·25	6280	+·002			
11·38						
M 11·297						
4·99	·1	480	+·003	....	In a small rockery, in garden, near the church; position good.	390.
5·00	·2	970	+·004			
5·00	·3	1480	+·001			
4·99	·4	1970	+·002			
M 4·995	·5	2480	−·001			
5·00	·1	495	correct.	....	In kitchen gardens, which slope towards S.W.; gauge is in the flattest part of them, and unsheltered.	391.
5·01	·2	980	+·002			
5·00	·3	1480	+·001			
4·99	·4	1950	+·007			
M 5·000	·5	2490	−·002			
5·00	·055	295	−·004	....	Old gauge, no longer used. The funnel has a very round rim; only the bottom of the measuring-glass remains.	392.
5·00						
5·00						
4·99						
M 4·998						
5·00	·1	480	+·003	N. Tree 31°.	In garden, clear except as noted.	393.
5·01	·2	950	+·008	S. Tree 42°.		
4·99	·3	1460	+·005			
5·00	·4	1970	+·003			
M 5·000	·5	2460	+·004			
8·00	·0–·1	1310	−·002	N.E. Trees 70°.	In kitchen garden, no better position available.	394.
8·10	·1–·2	1250	+·003	S.W. Trees 52°.		
7·97	·2–·3	1290	correct			
8·15	·3–·4	1300	−·001			
M 8·055						
7·98	·1	1290	−·002	N.E. House 30°.	On large lawn in front of house; good position.	395.
8·00	·2	2560	−·002	S. Trees 22°.		
7·98	·3	3840	−·003			
8·00	·4	5100	−·003			
M 7·990	·5	6330	correct			
8·00	·1	1280	−·001	S.W. House 50°.	Very bad position, on a roof quite commanded by others. No better position on the premises.	396.
8·00	·2	2580	−·003	W. House 50°.		
8·00	·3	3860	−·004	N.W. House 50°.		
8·00	·4	5100	−·002			
M 8·000	·5	6300	+·004			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Above sea-level.
						ft. in.	feet.
397.	1869. Oct. 1.	DEVON. Ivy Bridge. *DR. LIDDELL.* *Dr. Liddell.*	II	Liddell	....	3 0	145
398.	1870. May 5.	KENT. Heathfield Lodge, Chislehurst. *F. NUNES, ESQ.* *F. Nunes, Esq.*	XI	Negretti & Zambra	9 a.m. daily.	2 0	295
399.	May 5.	KENT. Heathfield Lodge, Chislehurst. *F. NUNES, ESQ.* *F. Nunes, Esq.*	X	Pastorelli	9 a.m. daily	1 0	295
400.	May 5.	KENT. Sidcup, Foot's Cray. *MISS BERENS.* *Miss Berens.*	III	Knight	weekly & 1st of month.	0 7	231
401.	May 5.	KENT. Bickley. *G. F. CHAMBERS, ESQ., F.R.A.S.* *G. F. Chambers, Esq., F.R.A.S.*	III	Casella	....	1 0	240
402.	May 5.	KENT. West Wickham. *REV. J. T. AUSTEN.* *Rev. J. T. Austen.*	X	Anon	....	1 3	257
403.	May 5.	KENT. Bromley Common. *REV. A. RAWSON.* *Rev. A. Rawson.*	X	Negretti & Zambra	9 a.m.	1 0	250
404.	May 19.	SURREY. Pyports, Cobham. *G. DINES, ESQ.* *G. Dines, Esq.*	X	Negretti & Zambra	9 a.m.	1 0	65
405.	May 19.	SURREY. Pyports, Cobham. *G. DINES, ESQ.* *G. Dines, Esq.*	XII	Casella	9 a.m.	1 0	65
406.	June 10.	HAMPSHIRE. Niton, Isle of Wight. *REV. R. C. KEMPE.* *Rev. R. C. Kempe.*	X	Negretti & Zambra	....	0 6	130
407.	July 25.	RADNORSHIRE. Heyhope Rectory. *REV. W. W. GRIFFITH.* *Rev. W. W. Griffith.*	XII	Casella	9 a.m.	1 0	690

RAIN-GAUGES (*continued*).

Diameters (that marked M=mean).	Equivalents of water. Scale-point.	Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
10·00 sq.	·0—·1	2560	—·001	W.N.W. Apple 50°.	Good position except as noted. Have been informed the tree has been removed.	397.
10·03	·1—·2	2560	—·001			
10·00	·2—·3	2540	correct.			
10·05						
M 10·020						
5·00	·1	500	—·001	....	On side of field, slightly sheltered from N., open in all other quarters.	398.
5·01	·2	980	—·003			
5·00	·3	1450	+·008			
5·01	·4	1950	+·007			
M 5·005	·5	2450	+·007			
8·00	·1	1250	+·001	....	Close to No. 398.	399.
8·00	·2	2540	correct.			
7·98	·3	3750	+·005			
8·02	·4	5050	+·002			
M 8·000	·5	6360	—·001			
5·02	·1	510	—·002	S.W. Cedar 48°.	Good position except as noted; to be moved about 100 ft. to N.; will then be slightly sheltered from N.E., but quite open to S.W.	400.
5·00	·2	1000	correct.			
5·00	·3	1480	+·004			
5·05	·4	1980	+·004			
M 5·018	·5	2500	—·001			
5·05	....	....	....	E. House 58°.	Gauge in garden border, funnel not level, glass inaccessible, as observer was absent.	401.
4·96						
4·98						
5·01						
M 5·000						
12·30	....	....	....	....	In kitchen garden on western slope, and near the top of a small hill. Observer absent, and measuring-apparatus inaccessible.	402.
12·20						
12·20						
12·25						
M 12·238						
8·00	·1	1300	—·003	....	Well placed in large kitchen garden.	403.
7·98	·2	2515	+·002			
8·00	·3	3750	+·004			
8·00	·4	5050	+·002			
M 7·995	·5	6350	—·001			
8·03	·1	1255	+·001	S.E. Fir 55°. N.W. Yew 40°.	Clear except as noted; very open to S.W.	404.
7·93	·2	2550	—·002			
8·03	·3	3800	—·001			
7·92	·4	5050	correct.			
M 7·978	·5	6310	correct.			
5·02	·1	495	correct.	....	Close to No. 404.	405.
4·99	·2	1000	—·002			
5·01	·3	1500	—·003			
4·97	·4	1980	correct			
M 4·998	·5	2460	+·003			
8·03	·1	1270	correct.	....	Fair position in small grass enclosure.	406.
7·98	·2	2550	—·001			
8·00	·3	3820	—·001			
7·98	·4	5100	—·002			
M 7·978	·5	6310	+·003			
5·00	·1	495	correct.	....	In excellent position in the Rectory grounds.	407.
4·99	·2	990	correct.			
5·00	·3	1490	—·001			
5·01	·4	1980	+·001			
M 5·000	·5	2480	correct.			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Height of gauge. Above sea-level.
	1870.					ft. in.	feet.
408.	July 26.	RADNORSHIRE. Cefnfaes, Rhayader. *MRS. JONES.* *Mrs. Jones.*	III	Anon	9 a.m.	1 0	885
409.	July 26.	MONTGOMERYSHIRE. Ystrad-olwyn-fawr, Llanidloes. *BRITISH ASSOCIATION.* *Mr. J. Jones.*	I	Anon	9 a.m. 1st	1 0	950
410.	July 26.	MONTGOMERYSHIRE. Dolenog, Llanidloes. *T. F. ROBERTS, ESQ.* *T. F. Roberts, Esq.*	III	Casella	a.m.	1 0	522
411.	July 26	MONTGOMERYSHIRE. Dylive, Head of River Clwyedog. *BRITISH ASSOCIATION.* *Mr. Isaac Jones.*	I	Anon	9 a.m. 1st of month.	......	1400
412.	July 27.	MONTGOMERYSHIRE. Capel Carno. *BRITISH ASSOCIATION.* *Mr. T. Bound.*	I	Anon	9 a.m. 1st of month.	1 0	550
413.	July 27.	MONTGOMERYSHIRE. Llwest fawr, Garthbibio. *BRITISH ASSOCIATION.* *Mr. Joseph Jones.*	I	Anon	9 a.m. 1st of month.	1 0	990
414.	July 28.	MONTGOMERYSHIRE. Head of River Vyrnwy, Llanwddyn. *BRITISH ASSOCIATION.* *Mr. John Gittens.*	I	Anon	9 a.m. 1st of month.	0 8	1740
415.	July 28.	MONTGOMERYSHIRE. Llanwddyn. *BRITISH ASSOCIATION.* *Mr. David Pugh.*	I	Anon	9 a.m. 1st of month.	0 7	750
416.	Aug. 2.	SUFFOLK. Barton Hall, Bury St. Edmunds. *SIR CHARLES BUNBURY.* *Mr. Allan.*	III	Casella	9 a.m.	1 0	200
417.	Aug. 2.	SUFFOLK. Ixworth, Bury St. Edmunds. *REV. W. STEGGALL.* *Rev. W. Steggall.*	XII	Casella	9 a.m.	1 6	125
418.	Aug. 2.	SUFFOLK. Barningham, Bury St. Edmunds. *J. FISON, ESQ.* *J. Fison, Esq.*	X	Negretti & Zambra	Irregular.	0 8	125

RAIN-GAUGES (*continued*).

Diameters (that marked M = mean).	Equivalents of water. Scale-point.	Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
4·98	·1	520	—·005	E. Tree 35°.	In garden sloping from the house towards the S., perfectly open from E.S.E. to W.S.W., and fairly so from other points.	408.
4·98	·2	1020	—·007	W. Tree 38°.		
4·98	·3	1500	—·004			
5·01	·4	2050	—·015			
M 4·988	·5	2480	—·003			
8·03	....	....	cylinder true and rod correct.	....	In field about one mile E. of Llangurig Church; very good position.	409.
8·00						
8·05						
8·00						
M 8·020						
5·02	·1	500	—·001	....	Gauge recently removed here from Broomcliff. Its future position will be on flat ground at the bottom of a rather narrow valley.	410.
4·98	·2	970	+·004			
5·00	·3	1470	+·004			
4·99	·4	1990	—·002			
M 4·998	·5	2470	+·002			
....	....	....	Rod correct.	....	Gauge could not be found in the absence of the observer, who failed to meet me. The ground is, however, level table land well suited for a gauge, and as it and the four following gauges were all made together, I have no doubt it is correct.	411.
7·98	....	....	Rod correct and gauge a true cylinder.	....	In field near Carno railway station; good position.	412.
8·03						
8·02						
8·02						
M 8·013						
8·00	....	....	Rod correct and gauge a true cylinder.	....	On summit of hill above Garthbibio. It is stuck in a bank, giving it rather an extreme exposure for so elevated a station.	413.
7·95						
8·05						
7·99						
M 7·998						
8·01	....	....	Rod correct and gauge a true cylinder.	....	On the flat top of a moor above Ennant, 4 miles W.N.W. of Llanwddyn, and ½ mile N. of Y. Gadfa.	414.
8·15						
8·00						
7·99						
M 8·038						
8·04	....	....	Rod correct and gauge a true cylinder.	....	In field a few hundred yards E. from Llanwddyn church, quite open. Doubt if observer is always reliable.	415.
8·06						
8·10						
8·02						
M 8·055						
4·99	·1	495	correct.	N. Sycamore 38°.	Previously examined in 1862 (see No. 27). Gauge in same position and carefully attended to. Owing to the absence of Ordnance bench-marks, the altitudes in this neighbourhood are still uncertain.	416.
5·00	·2	1000	—·001			
5·02	·3	1500	—·002			
5·00	·4	1990	—·001			
M 5·003	·5	2490	—·002			
4·97	·1	500	—·001	W.N.W. Laurel 35°	Good position at junction of roads north end of village.	417.
5·02	·2	980	+·002			
5·02	·3	1460	+·005			
4·98	·4	1950	+·006			
M 4·998	·5	2450	+·005			
8·03	·1	1350	—·007	W.S.W. House 55°	Very sheltered position, observer agreed to move it to a more suitable one.	418.
7·94	·2	2570	—·003	S.E. Poplars 60°.		
7·98	·3	3750	+·004			
8·01	·4	5040	+·002			
M 7·990	·5	6300	+·003			

EXAMINATION OF

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground	Above sea-level.
	1870.					ft. in.	feet.
419.	Aug. 3.	SUFFOLK. Dickleburgh, Diss. *F. DIX.* *F. Dix.*	II	Anon	....	3 0	118
420.	Aug. 3.	SUFFOLK. Yaxley, Eye. *REV. W. H. SEWELL.* *Rev. W. H. Sewell.*	X	Negretti & Zambra	9 a.m.	0 10	108
421.	Aug. 3.	SUFFOLK. Thwaite, Mendlesham. *MR. O. WHISTLECRAFT.* *Mr. O. Whistlecraft.*	....	Anon	Irregular.	2 8	117
422.	Aug. 3.	SUFFOLK. Walsham-Le-Willows. *MISS MARTINEAU.* *Miss Martineau.*	III	Casella	9 a.m.	0 11	100
423.	Aug. 8.	NORFOLK. West Tofts, Brandon. *BRITISH ASSOCIATION.* *Mr. R. Martin.*	XII	Casella	9 a.m.	1 1	91
424.	Aug. 31.	KENT. Heathfield Lodge, Chislehurst. *F. NUNES, Esq.* *F. Nunes, Esq.*	XII	Casella	....	1 0	295

Report on the Heat generated in the Blood in the process of Arterialization. By Arthur Gamgee, *M.D., F.R.S.E., Lecturer on Physiology in the Medical School, Surgeons' Hall, Edinburgh.*

So much has lately been done to extend our knowledge of the gases contained in the blood, of the blood-colouring-matter, and of its combinations with oxygen, that it seems strange that we should not yet possess reliable information on a matter which has long been the subject of speculation, and which assuredly admits of a positive solution, viz. on the changes in the temperature of blood during arterialization.

In this first and strictly preliminary Report it may be useful to ascertain the methods of investigation which have been employed by those observers who have hitherto attempted to throw light upon this matter.

RAIN-GAUGES (*continued*).

Diameters (that marked M=mean).	Equivalents of water. Scale-point	Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
8·75	....	....	....	S.W. Trees 58°.	Very old and dilapidated gauge in a very indifferent position; has been burst and mended many times, and is so out of repair that observer adds a variable correction to make it what he thinks it should be.	419.
8·80				N.E. Trees 55°.		
8·65						
M 8·733						
7·98	·1	1290	−·002	....	On Lawn near the church; good position.	420.
8·01	·2	2580	−·004			
7·98	·3	3860	−·005			
8·00	·4	5060	+·001			
M 7·993	·5	6300	+·003			
2·85sq.	·5	1000	+·019	N. Trees 43°.	An extraordinary gauge, consisting simply of a cubical leaden box, into which the rain falls; the depth is ascertained by dipping in a slate scale; the bottom thereof is now worn away; hence the large error, which, however, is partly corrected by the great loss which must arise from the absence of any provision against evaporation.	421.
2·90	1·0	2020	+·028			
2·85	1·49	3000	+·047			
2·87						
M 2·868						
5·00	·1	490	+·001	N.W. Fir 54°.	On lawn, rather sheltered as noted; was moved to centre of lawn quite free.	422.
4·98	·2	990	correct.			
4·99	·3	1470	+·003			
5·00	·4	1960	+·004			
M 4·993	·5	2470	correct.			
5·03	·1	510	−·003	N.W. Tree 52°.	In small garden E. of West Tofts church; no better position available.	423.
4·98	·2	995	−·001	W. Tree 52°.		
4·94	·3	1490	−·001	S.W. Tree 58°.		
5·05	·4	2000	−·003			
M 5·000	·5	2500	−·004			
4·95	·1	500	−·001	....	Close to No. 398.	424.
4·99	·2	980	+·001			
5·00	·3	1450	+·006			
5·00	·4	1950	+·004			
M 4·985	·5	2450	+·003			

These methods have been two, of which the one may be said to be indirect and the other direct; each, if properly carried out, should lead to most valuable results.

The first method which suggests itself is to determine the temperature of the blood in the right and left ventricles of the heart of a living animal. If our mode of experimenting were free from fallacy, and it resulted that the left side of the heart contained blood warmer than that of the right side, there would be no doubt as to the evolution of heat during the absorption of oxygen in the lungs; if, on the other hand, the temperature of the left side were the same as that of the right side, or lower, the question would still remain an open one, for heat might be evolved by the condensation and combination of oxygen in the lungs, yet the quantity might not be sufficient to counterbalance the loss of heat due to the evolution of large quantities of

watery vapour and carbonic acid in the lungs. The second, or direct method, which consists in agitating venous blood removed from the body with oxygen or atmospheric air, and ascertaining the changes in temperature which would then come into requisition.

Claude Bernard (Comptes Rendus, 1856) ascertained the temperature of the two sides of the heart by opening the internal jugular vein and the carotid artery in dogs, and thrusting very delicate self-registering thermometers into the right and left cavities. He arrived at the conclusion that the arterialized blood of the left side is invariably cooler than the venous blood of the right side. Mr. Savory, in a paper entitled "On the relative Temperature of Arterial and Venous Blood," pointed out that Claude Bernard's method of experimenting was not free from fallacy, as by interfering with the due action of the cardiac valves the thermometers would necessarily induce some disturbance in the pulmonary circulation. In his own experiments Mr. Savory, having exposed the heat of dogs under the influence of chloroform, punctured the right and left ventricles by means of a trocar, and then introduced into the cavities delicate thermometers. By this method of experimenting, he arrived at the conclusion that the blood of the left side of the heart is invariably warmer than that of the right side.

Very lately, in his work entitled "Leçons sur la Physiologie Comparée de la Respiration," M. Paul Bert has published the results of his own experiments, in which he introduced thermo-electric needles into the right and left sides of the heart in the same manner as M. Claude Bernard had done. He has confirmed the observations of Bernard; his experiments are, however, open to the same objections which were adduced by Savory against those of the earlier observer.

The second or direct method of research, to which I previously alluded, consists in experimenting with venous blood removed from the body, and ascertaining whether heat is evolved when it is agitated with air or pure oxygen. Although many authorities have been quoted as maintaining the opinion that when agitated with air venous blood is raised in temperature, the only authors whose experiments are recorded are Dr. John Davy and Mr. Savory. In his 'Researches, Physiological and Anatomical' (vol. i. p. 168), Davy attempted to answer the question, "When oxygen is absorbed by the blood, is there any production of heat?" He agitated a mixture of venous blood and metallic mercury in a glass phial with oxygen, and observed that a rise in temperature always occurred. Curiously, Dr. Davy does not appear to have considered that the rise in temperature must to a certain degree have been due to the agitation of the blood and mercury. Mr. Savory, in the Monograph previously quoted, indeed found that by Dr. Davy's method of experimenting no useful results could be obtained, as "in all cases the increase of temperature seemed to be the result of the agitation."

By shaking water in a similar manner with air, a small quantity of mercury being present, I have often raised its temperature, though to a less extent.

Before commencing independent experimental researches, with a view to determine, either by the direct or indirect method, the heat of arterialization, it appeared to me to be essential to undertake a set of experiments, with the object of determining with accuracy the specific heat of blood; and it is to a notice of these experiments that I confine my present Report, reserving the account of the experiments now in progress on the further question of the heat of arterialization to a future Report.

I believe I am quite accurate in stating that the specific heat of blood has

been determined by Dr. John Davy alone, his experiments being recorded in his previously quoted work (vol. p. 141), in a chapter entitled "On the Capacities of Venous and Arterial Blood for Heat." In his experiments he made use of defibrinated blood, and employed for the determination of specific heat the methods of mixture and rate of cooling. According to Davy, the specific heat of lambs' and sheeps' blood varied from 0·812 to 0·934 (water being 1·0).

The great discrepancy of these results made it most desirable that the determination should now be made in an accurate manner.

I employed invariably the method of mixture.

A flask furnished with a tubulature near its base was fixed in the centre of a water-bath, and from the flask a tube, also surrounded by hot water, proceeded, which communicated with the exterior by means of a stopcock. This flask was filled with mercury. The blood to be experimented upon was placed in a light and highly polished iron vessel, which was surrounded by cotton-wool, and placed in a glass beaker. The temperature of the blood and mercury was ascertained before and after mixture by means of a very delicate standard thermometer, made by Fastré of Paris, belonging to the Museum of Natural Philosophy of the University of Edinburgh. This thermometer admitted of being read very accurately to fiftieths of a degree Centigrade.

In my experiment, heated mercury was added to blood at a lower temperature.

The specific heat was determined by the usual formula.

C specific heat of blood.
M weight of blood.
T its temperature.
m weight of mercury.
t its temperature.
c' its specific heat, *i. e.* 0·033.
θ temperature of mixture of blood and mercury.
μ specific heat of vessel.

$$C=\frac{m(t-\theta)c'}{(M+\mu)(\theta-T)}.$$

The results of my experiments, which were all performed with perfectly fresh ox's blood, are exhibited below in a tabular form:—

No. of experiments.	M.	T.	m.	t.	μ.	θ.	C (specific heat).
		°	grammes.	°			
1.	76·15	12·06	1756·7	36·4	10·48	21·8	1·00
2.	249·95	18·45	1778·9	39·8	10·48	1·07	1·07
3.	224·35	16·30	1671·05	41·2	10·48	0·99	0·998
4.	224·05	22·00	1980·5	46·8	10·48	1·06	1·060
5.	283·60	23·00	2303·2	47·0	10·48	1·03	1·03
6.	217·55	15·50	1439·2	49·1	10·48	0·97	0·97

The above determinations were all made with the perfectly fresh blood of the ox; and they may, I think, be considered as representing very accurately the specific heat of blood.

They show that the specific heat of blood is not, as Davy supposed, con-

siderably below that of water, but almost exactly the same, the mean of all my results giving the coefficient of the specific heat of blood as 1·02. A knowledge of this was essential to the further progress of the research of which I hope on a future occasion to publish the definite results.

Edinburgh, September 19, 1870.

Report on the best means of providing for a uniformity of Weights and Measures, with reference to the Interests of Science. By a Committee, consisting of Sir JOHN BOWRING, *F.R.S.*, The Right Hon. C. B. ADDERLEY, *M.P.*, SAMUEL BROWN, *F.S.S.*, Dr. FARR, *F.R.S.*, FRANK P. FELLOWES, Professor FRANKLAND, *F.R.S.*, Professor HENNESSY, *F.R.S.*, JAMES HEYWOOD, *F.R.S.*, Sir ROBERT KANE, *F.R.S.*, Professor LEONE LEVI, *F.S.A.*, *F.S.S.*, Professor W. A. MILLER, *F.R.S.*, Professor RANKINE, *LL.D.*, *F.R.S.*, C. W. SIEMENS, *F.R.S.*, Colonel SYKES, *F.R.S.*, *M.P.*, Professor A. W. WILLIAMSON, *F.R.S.*, JAMES YATES, *F.R.S.*, Dr. GEORGE GLOVER, Sir JOSEPH WHITWORTH, *Bart.*, *F.R.S.*, J. R. NAPIER, H. DIRCKS, J. V. N. BAZALGETTE, W. SMITH, Sir W. FAIRBAIRN, *Bart.*, *F.R.S.*, *and* JOHN ROBINSON:—Professor LEONE LEVI, *Secretary.*

ALTHOUGH war has for a time unfortunately interrupted the progress of economic reforms on the Continent of Europe and may yet retard the realization of the desired uniformity in the weights, measures, and coins of all countries, your Committee have much pleasure in reporting that the prospects of the early attainment of such an object were never more satisfactory. Believing that in the interest of Science, and with a view to the progress of education, the universal adoption of the Metric System is by far the most preferable method for arriving at such uniformity, your Committee are glad to find that the Royal Standard Commissioners have reported that the time has now arrived when the law should provide, and facilities be afforded by the Government for the introduction and use of Metric Weights and Measures in the United Kingdom. For that purpose the Warden of the Standard has obtained a complete set of official standards of such weights and measures properly verified, and arrangements are in progress for laying down public standards of the imperial and Metric measure of length. The Metric Act of 1864 has not yet been amended, but the Board of Trade is only waiting the final report of the Commissioners, in order to introduce a complete measure on the subject of Weights and Measures early next Session. In accordance with the desire expressed by your Committee, the Board of Trade has published the first statistical paper showing the British Customs Tariff, and the Statistics of the Customs revenue and foreign Commerce of the United Kingdom, from 1840 to 1869, in the terms of the Imperial and Metric System, and also in pounds sterling and in francs. Your Committee have communicated with Her Majesty's Postmaster General with reference to the Postal Treaty concluded with France, and urged that the opportunity should be seized for introducing into this country a ten-gram weight. It is, however, with much regret and disappointment that they have learnt that, disregarding even

the recommendation of the Standard Commissioners, the Postal Authorities have decided to adopt the $\frac{1}{3}$ of an ounce as an equivalent for the 10 grams; for not only are the two weights not identical, but we miss a rare opportunity for introducing into practical use, part at least of a system, which there is every reason to believe will, sooner or later, become national. Apart from the action of the Government, there is ample evidence that the early introduction of the Metric System is desired by the people. In May last, an important conference was held in the rooms of the Society of Arts, when the following resolutions were unanimously carried:—

1. That the great inconvenience to Agriculture, Manufactures, and Commerce, as well as to Science, resulting from the numerous complicated and anomalous Weights and Measures now in use, whether by law or custom, in the British Empire, demands the attention of the Legislature at the earliest practicable time, with a view to the establishment of some convenient uniform Decimal system throughout the United Kingdom.

2. That the Standard Commissioners having recommended the abolition of Troy Weights, this Conference is of opinion that all those who now use the same should substitute for them, not the lb. Avoirdupois, but the Kilogram, with its divisions and multiples, by which another practical step will be made towards the complete adoption of the Metric System throughout the British Empire, which, in the opinion of this Meeting, is an object of the highest importance.

3. That in order to facilitate the speedy introduction of Metric Weights and Measures and an International Coinage, this Conference deems it highly desirable that Decimal Arithmetic, with the specialities of the Metric System, should be taught in all the Schools in the United Kingdom.

Your Committee have also much pleasure in reporting, that during the year, in consequence of general complaints of the numerous descriptions of weights and measures by which grain is sold in different markets of the kingdom, a Joint Committee of the Central Chamber of Agriculture and the International Decimal Association have produced a report to the following effect. From the report of that joint Committee, it appears that the extreme difference of practice in the weights and measures used in different markets of the United Kingdom, for the sale of grain and other agricultural products and manures, is the cause of considerable inconvenience and loss. The Banbury, Devonshire, Essex, Howdenshire, Kincardineshire, Leicestershire, Malton, Monmouthshire, Norfolk, North of England, North Riding of Yorkshire, Scottish, Warwickshire, and Worcestershire Chambers of Agriculture were unanimous in their opinion that steps should be taken for obtaining a uniform system as speedily as possible; and from long experience that Committee was convinced that no voluntary or permissive legislation, and that no local arrangement or understanding will enable us to realize the object in view. In the language used by more than one of such Chambers, "Whatever standard be decided upon, the same should be made compulsory throughout the country." Besides, however, a general testimony in favour of uniformity of Weights and Measures in the United Kingdom, the Committee found that a movement has been gaining ground for extending such uniformity among all countries. And the Committee were strongly impressed with the conviction that, dependent as we are upon foreign countries for the supply of grain, other agricultural products and manures, great advantage would be derived if, in making the necessary change, we could contribute to the realization of this larger object. It would save time, it would prevent errors, it would greatly facilitate commercial transactions, if grain

were quoted in the same manner in every market of the world, and if our merchants and corn-growers could understand the ordinary quotations from Stettin and Odessa as readily as those from their own home markets. Nor is the object far from practical attainment. The Committee learn that considerable progress has already been made in the great work; that a large number of countries, having an aggregate population of more than 200,000,000 (two hundred millions), both on the Baltic and the Mediterranean seas, and on the Atlantic and Pacific oceans, have agreed in adopting and are already using the Metric system; that this system has just been established throughout our Indian empire; and that in this kingdom, and in the United States of America, the use of the same weights and measures has been made legal and permissive. Under such circumstances, and believing that, if a change is to be made, it is best to endeavour to secure a system as perfect as possible, one not likely to be again altered, and one equally suitable to the general wants of all classes of the community, that Committee came to the conclusion that the best mode of obtaining a real and permanent uniformity in weights and measures applicable to the sale of grain and other agricultural products and manures, is by adapting our present practice to the metric system. With a view to this object, the Committee made the following recommendations:—

"(1.) That, in the opinion of this Committee, it is desirable that the Government should be requested to act upon the recommendations of the Standards Commissioners in their Second and Third Reports, by legislating, with the least practicable delay, in reference to the introduction of the Metric Weights and Measures in this country, and facilitating their use by making proper arrangements for the legal verification and stamping of such weights and measures.

"(2.) That the Chambers of Agriculture and the Cambers of Commerce be recommended to petition the Legislature to pass, with the least practicable delay, such enactments as will establish the kilogram with its decimal multiples and divisions as the standard unit of weight in lieu of the present pound avoirdupois and other imperial and customary weights.

"(3.) That, in the opinion of your Committee, the use of such standard weights should be made compulsory within a definite time; and, thenceforth, contracts made by any other weights should be invalid.

"(4.) That although the Central Chamber of Agriculture has recommended that grain should be sold by the 'cental' of 100 lb. (one hundred pounds), which is in use at Liverpool, yet, as your Committee find the general average weight of a sack of the different kinds of grain to be about 224 lb. (two hundred and twenty-four pounds), or the tenth part of a ton, they are of opinion that it would be desirable to substitute for the 'cental,' a weight of 100 (one hundred) kilogrammes (or, in other words, a 'quintal'), which only differs by a fraction from 220 lb. (two hundred and twenty pounds).

"(5.) That this report be printed and copies transmitted to all the Chambers of Agriculture and Chambers of Commerce, to Agricultural Societies, Farmers' Clubs, and Municipal Councils, with the request that they will circulate the same and consider the recommendations of this Committee at their earliest convenience."

From these and other circumstances of a like character, your Committee have reason to conclude that the Metric System is gaining in public favour, and they earnestly hope that Her Majesty's Government may not delay in adopting a bold course on the subject. No time certainly should be lost mean-

while in teaching the Metric System in all the schools; and it would be well if a knowledge of the same should be required at least in all the normal schools in the United Kingdom. Your Committee have deemed it advantageous to present a copy of the Mural Standard of the Metre and Yard procured from Mr. Casella, to the Mayor of Newcastle for public exhibition, Newcastle being the seat of extensive mechanical and chemical works, where the decimal measures of the metre and the gram are preferred to the corresponding measures and weight in the imperial system. Another copy of the same Mural Standard your Committee have presented to the Museum of Science and Art in Edinburgh, an institution very largely frequented by the people. And they have also purchased a complete set of all the weights and measures of the Metric System, with accompanying tables and diagrams, for the purpose of illustrating Lectures and offering information on the subject.

Your Committee have seen with much satisfaction the successful introduction of the Metric System into the Indian Empire. From a parliamentary paper recently published, it appears that the representations made by your Committee to Sir Stafford Northcote, the Secretary of State for India, has had much influence in inducing the Government of India to adopt the Metric in preference to any other system. Your Committee have taken much interest in the enlightened steps taken by Colonel Strachey in furtherance of this important reform. In Canada a Select Committee of the Senate reported in favour of a uniform International Decimal System of Weights, Measures, and Coins. And an International Standard Commission has been appointed to meet in Paris for the construction of new Primary Metric Standards. But how soon will that Commission meet, it is extremely difficult to say, since the breaking up of this unhappy war.

With regard to coinage, your Committee are informed that a Commission on the Monetary Standards held in Paris, after careful consideration, reported in favour of a single gold standard. But no practical step has hitherto been taken with regard to it, either here or elsewhere. Your Committee have done much to diffuse information on the general subject, but they feel that they have yet much to accomplish, especially in inducing the various learned bodies in different countries to adopt the same standard of money, weights, and measures as a common language. They therefore suggest the reappointment of the Metric Committee, and that another grant, of at least £25, be asked from the Committee of Recommendations, whereby further copies of the Mural Standard may be sent to towns and places where they may be seen and studied by large masses of the people, and for the general object of extending the knowledge of a question eminently calculated to further the progress of science and civilization.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

MATHEMATICS AND PHYSICS.

Address by J. Clerk Maxwell, *LL.D., F.R.S., President of the Section.*

At several of the recent Meetings of the British Association the varied and important business of the Mathematical and Physical Section has been introduced by an Address, the subject of which has been left to the selection of the President for the time being. The perplexing duty of choosing a subject has not, however, fallen to me.

Professor Sylvester, the President of Section A at the Exeter Meeting, gave us a noble vindication of pure mathematics by laying bare, as it were, the very working of the mathematical mind, and setting before us, not the array of symbols and brackets which form the armoury of the mathematician, or the dry results which are only the monuments of his conquests, but the mathematician himself, with all his human faculties directed by his professional sagacity to the pursuit, apprehension, and exhibition of that ideal harmony which he feels to be the root of all knowledge, the fountain of all pleasure, and the condition of all action. The mathematician has, above all things, an eye for symmetry; and Professor Sylvester has not only recognized the symmetry formed by the combination of his own subject with those of the former Presidents, but has pointed out the duties of his successor in the following characteristic note:—

"Mr. Spottiswoode favoured the Section, in his opening Address, with a combined history of the progress of Mathematics and Physics; Dr. Tyndall's address was virtually on the limits of Physical Philosophy; the one here in print," says Prof. Sylvester, "is an attempted faint adumbration of the nature of Mathematical Science in the abstract. What is wanting (like a fourth sphere resting on three others in contact) to build up the Ideal Pyramid is a discourse on the Relation of the two branches (Mathematics and Physics) to, their action and reaction upon, one another, a magnificent theme, with which it is to be hoped that some future President of Section A will crown the edifice and make the Tetralogy (symbolizable by A+A', A, A', AA') complete."

The theme thus distinctly laid down for his successor by our late President is indeed a magnificent one, far too magnificent for any efforts of mine to realize. I have endeavoured to follow Mr. Spottiswoode, as with far-reaching vision he distinguishes the systems of science into which phenomena, our knowledge of which is still in the nebulous stage, are growing. I have been carried by the penetrating insight and forcible expression of Dr. Tyndall into that sanctuary of minuteness and of power where molecules obey the laws of their existence, clash together in fierce

collision, or grapple in yet more fierce embrace, building up in secret the forms of visible things. I have been guided by Prof. Sylvester towards those serene heights

> "Where never creeps a cloud, or moves a wind,
> Nor ever falls the least white star of snow,
> Nor ever lowest roll of thunder moans,
> Nor sound of human sorrow mounts, to mar
> Their sacred everlasting calm."

But who will lead me into that still more hidden and dimmer region where Thought weds Fact, where the mental operation of the mathematician and the physical action of the molecules are seen in their true relation? Does not the way to it pass through the very den of the metaphysician, strewed with the remains of former explorers, and abhorred by every man of science? It would indeed be a foolhardy adventure for me to take up the valuable time of the Section by leading you into those speculations which require, as we know, thousands of years even to shape themselves intelligibly.

But we are met as cultivators of mathematics and physics. In our daily work we are led up to questions the same in kind with those of metaphysics; and we approach them, not trusting to the native penetrating power of our own minds, but trained by a long-continued adjustment of our modes of thought to the facts of external nature.

As mathematicians, we perform certain mental operations on the symbols of number or of quantity, and, by proceeding step by step from more simple to more complex operations, we are enabled to express the same thing in many different forms. The equivalence of these different forms, though a necessary consequence of self-evident axioms, is not always, to our minds, self-evident; but the mathematician, who by long practice has acquired a familiarity with many of these forms, and has become expert in the processes which lead from one to another, can often transform a perplexing expression into another which explains its meaning in more intelligible language.

As students of Physics we observe phenomena under varied circumstances, and endeavour to deduce the laws of their relations. Every natural phenomenon is, to our minds, the result of an infinitely complex system of conditions. What we set ourselves to do is to unravel these conditions, and by viewing the phenomenon in a way which is in itself partial and imperfect, to piece out its features one by one, beginning with that which strikes us first, and thus gradually learning how to look at the whole phenomenon so as to obtain a continually greater degree of clearness and distinctness. In this process, the feature which presents itself most forcibly to the untrained inquirer may not be that which is considered most fundamental by the experienced man of science; for the success of any physical investigation depends on the judicious selection of what is to be observed as of primary importance, combined with a voluntary abstraction of the mind from those features which, however attractive they appear, we are not yet sufficiently advanced in science to investigate with profit.

Intellectual processes of this kind have been going on since the first formation of language, and are going on still. No doubt the feature which strikes us first and most forcibly in any phenomenon, is the pleasure or the pain which accompanies it, and the agreeable or disagreeable results which follow after it. A theory of nature from this point of view is embodied in many of our words and phrases, and is by no means extinct even in our deliberate opinions.

It was a great step in science when men became convinced that, in order to understand the nature of things, they must begin by asking, not whether a thing is good or bad, noxious or beneficial, but of what kind is it? and how much is there of it? Quality and Quantity were then first recognized as the primary features to be observed in scientific inquiry.

As science has been developed, the domain of quantity has everywhere encroached on that of quality, till the process of scientific inquiry seems to have become simply the measurement and registration of quantities, combined with a mathematical discussion of the numbers thus obtained. It is this scientific method of directing our attention to those features of phenomena which may be regarded as quantities which brings physical research under the influence of mathematical reasoning. In

the work of the Section we shall have abundant examples of the successful application of this method to the most recent conquests of science; but I wish at present to direct your attention to some of the reciprocal effects of the progress of science on those elementary conceptions which are sometimes thought to be beyond the reach of change.

If the skill of the mathematician has enabled the experimentalist to see that the quantities which he has measured are connected by necessary relations, the discoveries of physics have revealed to the mathematician new forms of quantities which he could never have imagined for himself.

Of the methods by which the mathematician may make his labours most useful to the student of nature, that which I think is at present most important is the systematic classification of quantities.

The quantities which we study in mathematics and physics may be classified in two different ways.

The student who wishes to master any particular science must make himself familiar with the various kinds of quantities which belong to that science. When he understands all the relations between these quantities, he regards them as forming a connected system, and he classes the whole system of quantities together as belonging to that particular science. This classification is the most natural from a physical point of view, and it is generally the first in order of time.

But when the student has become acquainted with several different sciences, he finds that the mathematical processes and trains of reasoning in one science resemble those in another so much that his knowledge of the one science may be made a most useful help in the study of the other.

When he examines into the reason of this, he finds that in the two sciences he has been dealing with systems of quantities, in which the mathematical forms of the relations of the quantities are the same in both systems, though the physical nature of the quantities may be utterly different.

He is thus led to recognize a classification of quantities on a new principle, according to which the physical nature of the quantity is subordinated to its mathematical form. This is the point of view which is characteristic of the mathematician; but it stands second to the physical aspect in order of time, because the human mind, in order to conceive of different kinds of quantities, must have them presented to it by nature.

I do not here refer to the fact that all quantities, as such, are subject to the rules of arithmetic and algebra, and are therefore capable of being submitted to those dry calculations which represent, to so many minds, their only idea of mathematics.

The human mind is seldom satisfied, and is certainly never exercising its highest functions, when it is doing the work of a calculating machine. What the man of science, whether he is a mathematician or a physical inquirer, aims at is, to acquire and develope clear ideas of the things he deals with. For this purpose he is willing to enter on long calculations, and to be for a season a calculating machine, if he can only at last make his ideas clearer.

But if he finds that clear ideas are not to be obtained by means of processes the steps of which he is sure to forget before he has reached the conclusion, it is much better that he should turn to another method, and try to understand the subject by means of well-chosen illustrations derived from subjects with which he is more familiar.

We all know how much more popular the illustrative method of exposition is found, than that in which bare processes of reasoning and calculation form the principal subject of discourse.

Now a truly scientific illustration is a method to enable the mind to grasp some conception or law in one branch of science, by placing before it a conception or a law in a different branch of science, and directing the mind to lay hold of that mathematical form which is common to the corresponding ideas in the two sciences, leaving out of account for the present the difference between the physical nature of the real phenomena.

The correctness of such an illustration depends on whether the two systems of ideas which are compared together are really analogous in form, or whether, in other words, the corresponding physical quantities really belong to the same

mathematical class. When this condition is fulfilled, the illustration is not only convenient for teaching science in a pleasant and easy manner, but the recognition of the formal analogy between the two systems of ideas leads to a knowledge of both, more profound than could be obtained by studying each system separately.

There are men who, when any relation or law, however complex, is put before them in a symbolical form, can grasp its full meaning as a relation among abstract quantities. Such men sometimes treat with indifference the further statement that quantities actually exist in nature which fulfil this relation. The mental image of the concrete reality seems rather to disturb than to assist their contemplations.

But the great majority of mankind are utterly unable, without long training, to retain in their minds the unembodied symbols of the pure mathematician, so that, if science is ever to become popular, and yet remain scientific, it must be by a profound study and a copious application of those principles of the mathematical classification of quantities which, as we have seen, lie at the root of every truly scientific illustration.

There are, as I have said, some minds which can go on contemplating with satisfaction pure quantities presented to the eye by symbols, and to the mind in a form which none but mathematicians can conceive.

There are others who feel more enjoyment in following geometrical forms, which they draw on paper, or build up in the empty space before them.

Others, again, are not content unless they can project their whole physical energies into the scene which they conjure up. They learn at what a rate the planets rush through space, and they experience a delightful feeling of exhilaration. They calculate the forces with which the heavenly bodies pull at one another, and they feel their own muscles straining with the effort.

To such men momentum, energy, mass are not mere abstract expressions of the results of scientific inquiry. They are words of power, which stir their souls like the memories of childhood.

For the sake of persons of these different types, scientific truth should be presented in different forms, and should be regarded as equally scientific, whether it appears in the robust form and the vivid colouring of a physical illustration, or in the tenuity and paleness of a symbolical expression.

Time would fail me if I were to attempt to illustrate by examples the scientific value of the classification of quantities. I shall only mention the name of that important class of magnitudes having direction in space which Hamilton has called Vectors, and which form the subject-matter of the Calculus of Quaternions, a branch of mathematics which, when it shall have been thoroughly understood by men of the illustrative type, and clothed by them with physical imagery, will become, perhaps under some new name, a most powerful method of communicating truly scientific knowledge to persons apparently devoid of the calculating spirit.

The mutual action and reaction between the different departments of human thought is so interesting to the student of scientific progress, that, at the risk of still further encroaching on the valuable time of the Section, I shall say a few words on a branch of physics which not very long ago would have been considered rather a branch of metaphysics. I mean the atomic theory, or, as it is now called, the molecular theory of the constitution of bodies.

Not many years ago if we had been asked in what regions of physical science the advance of discovery was least apparent, we should have pointed to the hopelessly distant fixed stars on the one hand, and to the inscrutable delicacy of the texture of material bodies on the other.

Indeed, if we are to regard Comte as in any degree representing the scientific opinion of his time, the research into what takes place beyond our own solar system seemed then to be exceedingly unpromising, if not altogether illusory.

The opinion that the bodies which we see and handle, which we can set in motion or leave at rest, which we can break in pieces and destroy, are composed of smaller bodies which we cannot see or handle, which are always in motion, and which can neither be stopped nor broken in pieces, nor in any way destroyed or deprived of the least of their properties, was known by the name of the Atomic Theory. It was associated with the names of Democritus, Epicurus, and Lucretius,

and was commonly supposed to admit the existence only of atoms and void, to the exclusion of any other basis of things from the universe.

In many physical reasonings and mathematical calculations we are accustomed to argue as if such substances as air, water, or metal, which appear to our senses uniform and continuous, were strictly and mathematically uniform and continuous.

We know that we can divide a pint of water into many millions of portions, each of which is as fully endowed with all the properties of water as the whole pint was; and it seems only natural to conclude that we might go on subdividing the water for ever, just as we can never come to a limit in subdividing the space in which it is contained. We have heard how Faraday divided a grain of gold into an inconceivable number of separate particles, and we may see Dr. Tyndall produce from a mere suspicion of nitrite of butyle an immense cloud, the minute visible portion of which is still cloud, and therefore must contain many molecules of nitrite of butyle.

But evidence from different and independent sources is now crowding in upon us which compels us to admit that if we could push the process of subdivision still further we should come to a limit, because each portion would then contain only one molecule, an individual body, one and indivisible, unalterable by any power in nature.

Even in our ordinary experiments on very finely divided matter we find that the substance is beginning to lose the properties which it exhibits when in a large mass, and that effects depending on the individual action of molecules are beginning to become prominent.

The study of these phenomena is at present the path which leads to the development of molecular science.

That superficial tension of liquids which is called capillary attraction is one of these phenomena. Another important class of phenomena are those which are due to that motion of agitation by which the molecules of a liquid or gas are continually working their way from one place to another, and continually changing their course, like people hustled in a crowd.

On this depends the rate of diffusion of gases and liquids through each other, to the study of which, as one of the keys of molecular science, that unwearied inquirer into nature's secrets, the late Prof. Graham, devoted such arduous labour.

The rate of electrolytic conduction is, according to Wiedemann's theory, influenced by the same cause; and the conduction of heat in fluids depends probably on the same kind of action. In the case of gases, a molecular theory has been developed by Clausius and others, capable of mathematical treatment, and subjected to experimental investigation; and by this theory nearly every known mechanical property of gases has been explained on dynamical principles; so that the properties of individual gaseous molecules are in a fair way to become objects of scientific research.

Now Mr. Stoney has pointed out* that the numerical results of experiments on gases render it probable that the mean distance of their particles at the ordinary temperature and pressure is a quantity of the same order of magnitude as a millionth of a millimetre, and Sir William Thomson has since† shown, by several independent lines of argument, drawn from phenomena so different in themselves as the electrification of metals by contact, the tension of soap-bubbles, and the friction of air, that in ordinary solids and liquids the average distance between contiguous molecules is less than the hundred-millionth, and greater than the two-thousand-millionth of a centimetre.

These, of course, are exceedingly rough estimates, for they are derived from measurements some of which are still confessedly very rough; but if, at the present time, we can form even a rough plan for arriving at results of this kind, we may hope that, as our means of experimental inquiry become more accurate and more varied, our conception of a molecule will become more definite, so that we may be able at no distant period to estimate its weight with a greater degree of precision.

A theory, which Sir W. Thomson has founded on Helmholtz's splendid hydrodynamical theorems, seeks for the properties of molecules in the ring-vortices of a uniform, frictionless, incompressible fluid. Such whirling rings may be seen when

* Phil. Mag. Aug. 1868. † Nature, March 31, 1870.

an experienced smoker sends out a dexterous puff of smoke into the still air, but a more evanescent phenomenon it is difficult to conceive. This evanescence is owing to the viscosity of the air; but Helmholtz has shown that in a perfect fluid such a whirling ring, if once generated, would go on whirling for ever, would always consist of the very same portion of the fluid which was first set whirling, and could never be cut in two by any natural cause. The generation of a ring-vortex is of course equally beyond the power of natural causes, but once generated, it has the properties of individuality, permanence in quantity, and indestructibility. It is also the recipient of impulse and of energy, which is all we can affirm of matter; and these ring-vortices are capable of such varied connexions and knotted self-involutions, that the properties of differently knotted vortices must be as different as those of different kinds of molecules can be.

If a theory of this kind should be found, after conquering the enormous mathematical difficulties of the subject, to represent in any degree the actual properties of molecules, it will stand in a very different scientific position from those theories of molecular action which are formed by investing the molecule with an arbitrary system of central forces invented expressly to account for the observed phenomena.

In the vortex theory we have nothing arbitrary, no central forces or occult properties of any other kind. We have nothing but matter and motion, and when the vortex is once started its properties are all determined from the original impetus, and no further assumptions are possible.

Even in the present undeveloped state of the theory, the contemplation of the individuality and indestructibility of a ring-vortex in a perfect fluid cannot fail to disturb the commonly received opinion that a molecule, in order to be permanent, must be a very hard body.

In fact one of the first conditions which a molecule must fulfil is, apparently, inconsistent with its being a single hard body. We know from those spectroscopic researches which have thrown so much light on different branches of science, that a molecule can be set into a state of internal vibration, in which it gives off to the surrounding medium light of definite refrangibility—light, that is, of definite wavelength and definite period of vibration. The fact that all the molecules (say, of hydrogen) which we can procure for our experiments, when agitated by heat or by the passage of an electric spark, vibrate precisely in the same periodic time, or, to speak more accurately, that their vibrations are composed of a system of simple vibrations having always the same periods, is a very remarkable fact.

I must leave it to others to describe the progress of that splendid series of spectroscopic discoveries by which the chemistry of the heavenly bodies has been brought within the range of human inquiry. I wish rather to direct your attention to the fact that, not only has every molecule of terrestrial hydrogen the same system of periods of free vibration, but that the spectroscopic examination of the light of the sun and stars shows that, in regions the distance of which we can only feebly imagine, there are molecules vibrating in as exact unison with the molecules of terrestrial hydrogen as two tuning-forks tuned to concert pitch, or two watches regulated to solar time.

Now this absolute equality in the magnitude of quantities, occurring in all parts of the universe, is worth our consideration.

The dimensions of individual natural bodies are either quite indeterminate, as in the case of planets, stones, trees, &c., or they vary within moderate limits, as in the case of seeds, eggs, &c.; but even in these cases small quantitative differences are met with which do not interfere with the essential properties of the body.

Even crystals, which are so definite in geometrical form, are variable with respect to their absolute dimensions.

Among the works of man we sometimes find a certain degree of uniformity.

There is a uniformity among the different bullets which are cast in the same mould, and the different copies of a book printed from the same type.

If we examine the coins, or the weights and measures, of a civilized country, we find a uniformity, which is produced by careful adjustment to standards made and provided by the state. The degree of uniformity of these national standards is a measure of that spirit of justice in the nation which has enacted laws to regulate them and appointed officers to test them.

This subject is one in which we, as a scientific body, take a warm interest; and you are all aware of the vast amount of scientific work which has been expended, and profitably expended, in providing weights and measures for commercial and scientific purposes.

The earth has been measured as a basis for a permanent standard of length, and every property of metals has been investigated to guard against any alteration of the material standards when made. To weigh or measure any thing with modern accuracy, requires a course of experiment and calculation in which almost every branch of physics and mathematics is brought into requisition.

Yet, after all, the dimensions of our earth and its time of rotation, though, relatively to our present means of comparison, very permanent, are not so by any physical necessity. The earth might contract by cooling, or it might be enlarged by a layer of meteorites falling on it, or its rate of revolution might slowly slacken, and yet it would continue to be as much a planet as before.

But a molecule, say of hydrogen, if either its mass or its time of vibration were to be altered in the least, would no longer be a molecule of hydrogen.

If, then, we wish to obtain standards of length, time, and mass which shall be absolutely permanent, we must seek them not in the dimensions, or the motion, or the mass of our planet, but in the wave-length, the period of vibration, and the absolute mass of these imperishable and unalterable and perfectly similar molecules.

When we find that here, and in the starry heavens, there are innumerable multitudes of little bodies of exactly the same mass, so many, and no more, to the grain, and vibrating in exactly the same time, so many times, and no more, in a second, and when we reflect that no power in nature can now alter in the least either the mass or the period of any one of them, we seem to have advanced along the path of natural knowledge to one of those points at which we must accept the guidance of that faith by which we understand that "that which is seen was not made of things which do appear."

One of the most remarkable results of the progress of molecular science is the light it has thrown on the nature of irreversible processes—processes, that is, which always tend towards and never away from a certain limiting state. Thus, if two gases be put into the same vessel, they become mixed, and the mixture tends continually to become more uniform. If two unequally heated portions of the same gas are put into the vessel, something of the kind takes place, and the whole tends to become of the same temperature. If two unequally heated solid bodies be placed in contact, a continual approximation of both to an intermediate temperature takes place.

In the case of the two gases, a separation may be effected by chemical means; but in the other two cases the former state of things cannot be restored by any natural process.

In the case of the conduction or diffusion of heat the process is not only irreversible, but it involves the irreversible diminution of that part of the whole stock of thermal energy which is capable of being converted into mechanical work.

This is Thomson's theory of the irreversible dissipation of energy, and it is equivalent to the doctrine of Clausius concerning the growth of what he calls Entropy.

The irreversible character of this process is strikingly embodied in Fourier's theory of the conduction of heat, where the formulæ themselves indicate, for all positive values of the time, a possible solution which continually tends to the form of a uniform diffusion of heat.

But if we attempt to ascend the stream of time by giving to its symbol continually diminishing values, we are led up to a state of things in which the formula has what is called a critical value; and if we inquire into the state of things the instant before, we find that the formula becomes absurd.

We thus arrive at the conception of a state of things which cannot be conceived as the physical result of a previous state of things, and we find that this critical condition actually existed at an epoch not in the utmost depths of a past eternity, but separated from the present time by a finite interval.

This idea of a beginning is one which the physical researches of recent times have brought home to us, more than any observer of the course of scientific thought in former times would have had reason to expect.

But the mind of man is not, like Fourier's heated body, continually settling down into an ultimate state of quiet uniformity, the character of which we can already predict; it is rather like a tree, shooting out branches which adapt themselves to the new aspects of the sky towards which they climb, and roots which contort themselves among the strange strata of the earth into which they delve. To us who breathe only the spirit of our own age, and know only the characteristics of contemporary thought, it is as impossible to predict the general tone of the science of the future as it is to anticipate the particular discoveries which it will make.

Physical research is continually revealing to us new features of natural processes, and we are thus compelled to search for new forms of thought appropriate to these features. Hence the importance of a careful study of those relations between Mathematics and Physics which determine the conditions under which the ideas derived from one department of physics may be safely used in forming ideas to be employed in a new department.

The figure of speech or of thought by which we transfer the language and ideas of a familiar science to one with which we are less acquainted may be called Scientific Metaphor.

Thus the words Velocity, Momentum, Force, &c. have acquired certain precise meanings in Elementary Dynamics. They are also employed in the Dynamics of a Connected System in a sense which, though perfectly analogous to the elementary sense, is wider and more general.

These generalized forms of elementary ideas may be called metaphorical terms in the sense in which every abstract term is metaphorical. The characteristic of a truly scientific system of metaphors is that each term in its metaphorical use retains all the formal relations to the other terms of the system which it had in its original use. The method is then truly scientific—that is, not only a legitimate product of science, but capable of generating science in its turn.

There are certain electrical phenomena, again, which are connected together by relations of the same form as those which connect dynamical phenomena. To apply to these the phrases of dynamics with proper distinctions and provisional reservations is an example of a metaphor of a bolder kind; but it is a legitimate metaphor if it conveys a true idea of the electrical relations to those who have been already trained in dynamics.

Suppose, then, that we have successfully introduced certain ideas belonging to an elementary science by applying them metaphorically to some new class of phenomena. It becomes an important philosophical question to determine in what degree the applicability of the old ideas to the new subject may be taken as evidence that the new phenomena are physically similar to the old.

The best instances for the determination of this question are those in which two different explanations have been given of the same thing.

The most celebrated case of this kind is that of the corpuscular and the undulatory theories of light. Up to a certain point the phenomena of light are equally well explained by both; beyond this point, one of them fails.

To understand the true relation of these theories in that part of the field where they seem equally applicable we must look at them in the light which Hamilton has thrown upon them by his discovery that to every brachistochrone problem there corresponds a problem of free motion, involving different velocities and times, but resulting in the same geometrical path. Professor Tait has written a very interesting paper on this subject.

According to a theory of electricity which is making great progress in Germany, two electrical particles act on one another directly at a distance, but with a force which, according to Weber, depends on their relative velocity, and according to a theory hinted at by Gauss, and developed by Riemann, Lorenz, and Neumann, acts not instantaneously, but after a time depending on the distance. The power with which this theory, in the hands of these eminent men, explains every kind of electrical phenomena must be studied in order to be appreciated.

Another theory of electricity, which I prefer, denies action at a distance and attributes electric action to tensions and pressures in an all-pervading medium, these stresses being the same in kind with those familiar to engineers, and the medium being identical with that in which light is supposed to be propagated.

Both these theories are found to explain not only the phenomena by the aid of which they were originally constructed, but other phenomena, which were not thought of or perhaps not known at the time; and both have independently arrived at the same numerical result, which gives the absolute velocity of light in terms of electrical quantities.

That theories apparently so fundamentally opposed should have so large a field of truth common to both is a fact the philosophical importance of which we cannot fully appreciate till we have reached a scientific altitude from which the true relation between hypotheses so different can be seen.

I shall only make one more remark on the relation between Mathematics and Physics. In themselves, one is an operation of the mind, the other is a dance of molecules. The molecules have laws of their own, some of which we select as most intelligible to us and most amenable to our calculation. We form a theory from these partial data, and we ascribe any deviation of the actual phenomena from this theory to disturbing causes. At the same time we confess that what we call disturbing causes are simply those parts of the true circumstances which we do not know or have neglected, and we endeavour in future to take account of them. We thus acknowledge that the so-called disturbance is a mere figment of the mind, not a fact of nature, and that in natural action there is no disturbance.

But this is not the only way in which the harmony of the material with the mental operation may be disturbed. The mind of the mathematician is subject to many disturbing causes, such as fatigue, loss of memory, and hasty conclusions; and it is found that, from these and other causes, mathematicians make mistakes.

I am not prepared to deny that, to some mind of a higher order than ours, each of these errors might be traced to the regular operation of the laws of actual thinking; in fact we ourselves often do detect, not only errors of calculation, but the causes of these errors. This, however, by no means alters our conviction that they are errors, and that one process of thought is right and another process wrong.

One of the most profound mathematicians and thinkers of our time, the late George Boole, when reflecting on the precise and almost mathematical character of the laws of right thinking as compared with the exceedingly perplexing though perhaps equally determinate laws of actual and fallible thinking, was led to another of those points of view from which Science seems to look out into a region beyond her own domain.

"We must admit," he says, "that there exist laws" (of thought) "which even the rigour of their mathematical forms does not preserve from violation. We must ascribe to them an authority, the essence of which does not consist in power, a supremacy which the analogy of the inviolable order of the natural world in no way assists us to comprehend."

Mathematics.

On the Problem of the in-and-circumscribed Triangle. *By* Professor A. Cayley, *LL.D., F.R.S.*

I have recently accomplished the solution of this problem, which I spoke of at the Meeting in 1864. The problem is as follows: required the number of the triangles the angles of which are situate in a given curve or curves, and the sides of which touch a given curve or curves. There are in all 52 cases of the problem, according as the curves which contain the angles and are touched by the sides are distinct curves, or are any or all of them the same curve. The first and easiest case is when the curves are all of them distinct; the number of triangles is here $=2ace$BDF, where a, c, e are the *orders* of the curves containing the angles (or, say, of the angle-curves) respectively; and B, D, F are the *classes* of the curves touched by the sides (or, say, of the side-curves) respectively. An interesting case is when the angle-curves are one and the same curve; or, say, $a=c=e$ (where the sign $=$ is used to denote the identity of the curves); the number of triangles is here

$= \{2a(a-1)(a-2)+A\}$ BDF, where a, A are the order and class of the curve $a=c=e$. In the reciprocal case, where the side-curves are one and the same curve, say B=D=F, we have of course a like formula, viz. the number of triangles is here $= \{2B(B-1)(B-2)+b\}\,ace$, where B, b are the class and order of the curve B=D=F. The last and most difficult case is when the six curves are all of them one and the same curve, say $a=c=e=$B=D=F; the number of triangles is here = one-sixth of

$$\begin{array}{l} A^4(\;.\quad.\quad.\quad.\quad.+\;1), \\ +A^3(\;.\quad 2a^3-\;18a^2+\;52a-\;46) \\ +A^2(\;.\;-18a^3+162a^2-420a+221) \\ +A\;(\;.\quad 52a^3-420a^2+704a+172) \\ +\quad 1a^4-46a^3+221a^2+172a \\ +\,\alpha\left\{\begin{array}{l} A^2(\;.\quad.\quad.\quad -9 \\ +A\;(\;.\quad.\quad -12a+135 \\ \qquad\quad -9a^2+135a-600 \end{array}\right\}, \end{array}$$

where a is the order, A the class of the curve; α is the number, three times the class + the number of cusps, or (what is the same thing) three times the order + the number of inflexions.

On a Correspondence of Points and Lines in Space.
By Professor A. Cayley, *LL.D., F.R.S.*

Nine points in a plane may be the intersection of two (and therefore of an infinite series of) cubic curves; say, that the nine points are an "ennead:" and similarly nine lines through a point may be the intersection of two (and therefore of an infinite series of) cubic cones; say, the nine lines are an ennead. Now, imagine (in space) any 8 given points; taking a variable point P, and joining this with the 8 points, we have through P 8 lines, and there is through P a ninth line completing the ennead; this is said to be the corresponding line of P. We have thus to any point P a single corresponding line through the point P; this is the correspondence referred to in the heading, and which I would suggest as an interesting subject of investigation to geometers. Observe, that considering the whole system of points in space, the corresponding lines are a triple system of lines, *not* the whole system of lines in space. It is thus, not any line whatever, but only a line of the triple system, which has on it a corresponding point. But as to this some explanation is necessary; for starting with an arbitrary line, and taking upon it a point P, it would seem that P might be so determined that the given line and the lines from P to the eight points should form an ennead,—that is, that the arbitrary line would have upon it a corresponding point or points.

The question of the foregoing species of correspondence was suggested to me by the consideration of a system of 10 points, such that joining any one whatever of them with the remaining nine points, the nine lines thus obtained form an ennead; or, say, that each of the 10 points is the "enneadic centre" of the remaining nine. I have been led to such a system of 10 points by my researches upon Quartic surfaces; but I do not as yet understand the theory.

The small oscillations of a Particle and of a Rigid Body. *By* Robert Stawell Ball, *A.M., Professor of Applied Mathematics and Mechanism, Royal College of Science for Ireland.*

I. *Introductory.*

Laplace investigated the small oscillations of a particle on a sphere, Poisson solved a special case of the same problem on the ellipsoid, Lagrange discovered the general laws of small oscillations, and his methods have been improved by Messrs. Thomson and Tait; the results of which the following is an abstract, have been obtained by a union of the method of Lagrange in its improved form with

some elegant theorems of kinematics discovered by M. Chasles. Demonstrations of some of the theorems here enunciated will be found in two papers written by the author.

"On the small oscillations of a Particle on a Surface under the action of any Forces," Quarterly Journal of Mathematics, No. 39, 1869.

"On the small oscillations of a Rigid Body about a Fixed Point under the action of any Forces, and more particularly when gravity is the only force acting," Transactions of the Royal Irish Academy, vol. xxiv. Science, part xvi.

II. *A Particle.*

1. There are in general three lines called *normal lines*, such that whatever be the small oscillations of a particle, free in space, the movement is compounded of simple harmonic vibrations along the normal lines.

2. When the forces have a potential, a constant small quantity of energy would draw the particle along any radius vector from its position of rest to the surface of a certain ellipsoid; the normal lines are in the principal directions of this ellipsoid, and the lengths of the isochronous simple pendulums are proportional to the squares of its principal axes.

3. When the particle is constrained to a surface, the motion is compounded of vibrations in two directions on the surface, and when the forces have a potential, the tangent lines to these directions are at right angles.

III. *A Free Rigid Body.*

4. A free rigid body may receive any displacement by being screwed along an axis in space, the distance it travels along the axis when turned through the unit of angle being termed the pitch of the screw.

5. The movement of a free rigid body, when making small oscillations, is compounded of six normal movements, each consisting of a to-and-fro vibration about a *normal screw*, the position, pitch, and period of which depend upon the forces.

6. Whatever be the initial motion of the body, supposed small, it may be distributed uniquely among the six normal screws, and thus the entire motion is determined.

IV. *A Constrained Rigid Body.*

7. If a rigid body have k degrees of freedom, its small oscillations are compounded of vibrations about k normal screws.

8. A body capable of turning around a fixed axis and sliding along it, has two degrees of freedom; its motion is compounded of that about two normal screws whose pitch is different, but both of which lie in the fixed axis.

9. A body three points of which are limited to a plane, has three degrees of freedom; its motion is compounded of vibrations about three normal screws whose pitch is zero, and whose directions are perpendicular to the plane.

10. A body rotating about a fixed point has three degrees of freedom; its motion is compounded of vibrations about three normal screws whose pitch is zero, and whose directions pass through the point.

N.B.—The screws in this case may be conveniently called the *normal axes*.

V. *A Rigid Body rotating about a Point, the Forces having a Potential.*

11. The body may be moved from one position to any other position by rotation about a certain axis, passing through the point through a certain angle; this axis and angle are called the *axis of displacement* and the *angle of displacement* respectively.

12. On an axis through the point, take a radius vector proportional to the small angular velocity, which a small quantity of energy would be able to communicate to the body about the axis. The quantity of energy being constant, the locus of this point on different axes is the momental ellipsoid.

13. On an axis through the point, take a radius vector proportional to the small angle through which a small quantity of energy would be able to rotate the body about the axis from its position of equilibrium against the forces. The quantity of energy being constant, the locus of this point on different axes may be called the *ellipsoid of equal energy*.

14. The three common conjugate diameters of the momental ellipsoid and the

ellipsoid of equal energy are the normal axes; the body would vibrate about each of these axes, as about a fixed axis, and its motion is always compounded of vibrations about these axes.

15. The length of the simple pendulum isochronous with the vibration about each normal axis is proportional to the square of the ratio of the corresponding diameter in the ellipsoid of equal energy to that of the momental ellipsoid.

16. The body is slightly disturbed from its position of rest by rotation about an axis of displacement through an angle of displacement, and also by receiving a small angular velocity about an initial instantaneous axis; this displacement and velocity may be uniquely resolved into corresponding displacements and angular velocities about the normal axes, and thus the motion of the body is completely determined.

VI. *A Rigid Body rotating about a fixed Point, Gravity being the only Force acting.*

17. A plane drawn in the momental ellipsoid conjugate to the vertical through the point of supension is called the conjugate plane.

18. For small oscillations to be possible, the instantaneous axis must initially lie in the conjugate plane, and it will continue there throughout the motion.

19. There are two normal axes which are thus constructed. Draw an ellipsoid whose axes are in the same directions as, and proportional to, the squares of those of the momental ellipsoid, the common conjugate diameters of the sections of these ellipsoids made by the conjugate plane are the normal axes.

20. The normal axes are not at right angles, except when the centre of gravity lies in one of the principal planes, about the point of suspension; but a vertical plane drawn through one normal axis is always perpendicular to a vertical plane drawn through the other normal axis.

21. The body would vibrate about either of these normal axes as about a fixed axis, and any small oscillation is compounded of simple vibrations about the normal axes.

Special attention is directed to the theorem of paragraph 19, which contains the solution of the conical pendulum under its most general form.

On an Unexplained Contradiction in Geometry. *By* W. K. Clifford, *M.A.*

Observations on Boole's 'Laws of Thought.' *By the late* R. Leslie Ellis. *Communicated by the* Rev. Robert Harley, *F.R.S.*

It appears to be assumed in Chapter III. Section 8, that in deriving one conception from another the mind always moves, so to speak, along the line of predicamentation, always passes from the genus to the species. No doubt everything stands in relation to something else, as the species to its genus, and consequently the symbolical language proposed is in extent perfectly general, that is, it may be applied to all the objects in the universe. But I venture to doubt whether it can express explicitly all the relations between ideas which really exist, all the threads of connexion which lead the mind from one to the other. It seems to me that the mind passes from idea to idea in accordance with various principles of suggestion, and that, in correspondence with the different classes of such principles of suggestion, we ought to recognize different branches of the general theory of inference. This leads me to a further doubt whether logic and the science of quantity can in any way be put in antithesis to one another. From the notion of an apple we may proceed to that of two apples, and so on in a process of aggregation which is the foundation of the science of discrete quantity. Or again, from the notion of an apple we may proceed to that of a red apple; and this movement of the mind in *lineâ predicamentali* is the foundation of ordinary logic. But it is plain *à priori* that there are other principles of suggestion besides these two, and the following considerations lead me to think that there are other exercises of the reasoning faculty than those included in the two sciences here referred to. In the first place, certain inferences not included in the ordinary processes of conversion and syllogism were recognized as exceptional cases by the old logicians. Leibnitz has

mentioned some with the remark that they do not depend upon the *dictum de omni et nullo*, but on something of equivalent evidence. The only question is whether we should be right in considering these cases as exceptions, and if they are so, to what they owe their existence. One instance is the *inversio relationis*, *e. g.*, Noah is Shem's father, therefore Shem is Noah's son. Here we pass from the idea of Shem to that of his father, and *vice versâ*. The movement of the mind is along a track distinct from that which it follows, either in algebra or what we commonly call logic. The perception of the truth of the inference depends on a recognition of the correlation of the two ideas, father and son. Again, take a similar instance. Prince Albert sat at the Emperor's right hand, therefore the Emperor sat at Prince Albert's left hand. How shall we express such inferences symbolically? Let S be Shem, N Noah, f father, s son:

$$N=fS,$$
$$Sf=1.$$

Eliminating f between these two equations, we get

$$S=sN.$$

Nothing can be simpler than this; but the symbols s, f are of a distinct nature from those employed in the 'Laws of Thought;' for fA does not denote a species of A, but an idea standing in a different relation to it. The distinction between these two kinds of symbols becomes more manifest when we reflect that f^2 is not identical with f, but denotes "father of father," or grandfather. Now I do not see how these cases of inversion of relation are to be dealt with symbolically without the introduction of such symbols. In the following examples I confine myself to the cases afforded by relationship, and the succession of generations.

Let A, B, C denote three persons, s son, g grandson; then if B is A's son and C is B's, C is A's grandson, which we may express symbolically by the following equations:—

$$B=sA,\ C=sB,\ s^2=g.$$

Eliminating B and s, we get $C=gA$. It would be more accurate in these examples to introduce a symbol x or y to indicate that B is only one of the possible sons of A, an individual ranged under the species sA. I shall do that in the next example, in which the word son is replaced by the more general term descendant, denoted by d. The equations will now be

$$B=xdA,\ C=ydB,\ d^2=zd,$$

viz. a descendant not of the first generation. The result of eliminating B now is,

$$C=ydxdA;$$

but by a principle about to be noticed $dx=x'd$, therefore $C=yx'zdA$, or C is included in the class of descendants of A.

The principle just used forms one of the recognized examples of an inference not lying within the domain of Aristotelian logic. It was called "*transitio ex recto in obliquum*." Whately, though he says nothing of its nature, gives in his praxis of examples one which depends upon it. A negro is a man, therefore he who kills a negro kills a man. Let this derived notion killing be denoted by f, which may serve to indicate a general functional dependence, then M and N denoting man and negro respectively, we have the following equations:—

$$N=xM,\ fx=x'f;$$
$$\therefore fN=x'fM,$$

or the killing of a negro is a kind of homicide. The evidence of the truth of the equation $fx=x'f$ is the same as that in favour of the equation $xy=yx$, when x and y both belong to the kind of symbols used in the 'Laws of Thought.' I shall not stop to inquire into the limitations which it may perhaps require.

The general truth of the equations

$$x^2=x \text{ and } xy=yx$$

appears to suffer another exception in the case relative terms, that is, of adjectives of which the interpretation is functional of the object to which they are applied. A small St. Bernard dog is not *simpliciter* a small dog; the word meaning that which is less than the medium size of the class of objects to which it is applied.

Here neither $s^2=s$ nor $sx=xs$. If we say that in order to save whole these equations we may employ a different symbol for every application of the adjective small, how can we express the meaning which is common to them all, and in virtue of which the word small exists as an element of language?

Diffident as I am with respect to all these remarks on a method in which I find so much to admire, I am yet more so with respect to the following. But it seems to me that we cannot say that

$$x(1-x)=0$$

expresses *proprio vigore*, that is, in virtue of antecedent conventions, what is called the principle of contradiction.

In ordinary language we have words which, independently of this principle, express negation; we say red, not red, and the like; but in the 'Laws of Thought' there is no other means of expressing not red than by $1-x$, x denoting red.

Now the interpretation of this symbol $1-x$ seems to me to be given by the principle of contradiction, and therefore I should rather say that the equation $x(1-x)=0$ is interpreted by that principle than that it expresses it. In accordance with this view, the equation $x^2=x$ would appear to be independent of the principle of contradiction.

On Boole's 'Laws of Thought.' By the Rev. ROBERT HARLEY, *F.R.S.*

This paper was intended as a supplement to some "Remarks on Boole's Mathematical Analysis of Logic," which the author submitted to the Section at the Nottingham Meeting, an abstract of which was printed in the Report for 1866. (See Transactions of the Sections, pp. 3–6.)

From the logical equation $x^2=x$, the equation $x-x^2=0$ is derived by subtracting x^2 from both members, and the result is put under the form $x(1-x)=0$ by the law of distribution. It is to be observed, however, that at every step of the process the principle of identity $x=x$ is assumed, and in Boole's interpretation of the final result the same principle is used, for it is implied that the x without the brackets is identical with the x within. Further, in the final interpretation not only is the principle of contradiction (or non-contradiction) employed, as Leslie Ellis points out in the latter part of his 'Observations,' but the principle of excluded middle is also employed. For in interpreting $1-x$ to mean not-x, it is tacitly assumed that every one of the things of which the universe, represented by unity, is made up, is either x or not x. It would thus appear that these three principles, identity, contradiction, and excluded middle, are incapable of being reduced to more elementary truths. They are axiomatic, and Boole made use of them unconsciously in framing his laws of logical interpretation. ('Laws of Thought,' chap. iii. prop. iv.)

In chap. iii. § 5, Boole, by three different methods, one of which is partly logical, and the other two are wholly algebraical, deduces the equation

$$f(1)f(0)=0$$

from the equation for the expansion or development of any logical function $f(x)$, viz.

$$f(x)=f(1)x+f(0)(1-x),$$

where $f(x)$ may or may not involve other class symbols than x. The latter equation is established in chap. v. § 10, by means of the principle that it is lawful to treat x as a quantative symbol susceptible only of the values 0 and 1. But it is worthy of notice that the former equation may be directly established by means of the same principle. For, treating $f(x)=0$ as an algebraic equation, of which the root x has only the values 1 and 0, we have at once, by the theory of equations,

$$f(1)f(0)=0.$$

The influence of Boole's ideas may be traced in works apparently so diverse as Professor W. Stanley Jevons's 'Substitution of Similars,' Professor P. G. Tait's 'Quaternions,' and Sir Benjamin Brodie's 'Calculus of Chemical Operations.' The system of logic proposed by Mr. Jevons is closely analogous to, and in some respects identical with, that given by Boole; but it is distinguished from the latter by the rejection of the calculus of 1 and 0. In a little work entitled "Pure Logic, or the

Logic of Quality apart from Quantity," Mr. Jevons has urged various objections to certain parts of Boole's system, more particularly to the numerical calculus. The author of this paper has briefly considered those objections in the concluding portion of an article on "Boole's Life and Writings," which he contributed to the July Number of the British Quarterly Review for 1866 (pp. 141–181).

Hamilton's theory of quaternions, as expounded by Prof. Tait, has its logical basis in principles which were first brought clearly to light in the course of Boole's remarkable inquiries. No one can read the earlier chapters of Prof. Tait's 'Quaternions,' and compare them with the earlier chapters of Boole's 'Laws of Thought,' without being struck with the similarity, not to say the identity, of many of the processes employed in both works. Treating of the properties of the quaternion symbols S, K, V, the expounder of Hamilton's system remarks, "It is curious to compare the properties of these quaternion symbols with the Elective Symbols of Logic, as given in Boole's wonderful treatise on the 'Laws of Thought,' and to think that the same grand science of mathematical analysis, by processes remarkably similar to each other, reveals to us truths in the science of *position* far beyond the powers of the geometer, and truths of deductive reasoning to which unaided thought could never have led the logician." (Tait's Quaternions, p. 50, footnote.)

Sir Benjamin Brodie has endeavoured to do for chemistry what Boole has done for logic,—to reduce it under the domain of mathematics, using the term "mathematics" in the enlarged sense, explained in the author's former communication. Of the validity of Sir Benjamin's proposed "method for the investigation, by means of symbols, of the laws of the distribution of weight in chemical change," it is not necessary to speak here. But that method is interesting, as being undoubtedly the first attempt to "free the science of chemistry from the trammels imposed upon it by accumulated hypotheses, and to endow it with the most necessary of all the instruments of progressive thought, an exact and rational language." Sir Benjamin's system was evidently suggested by Boole's 'Laws of Thought.' Whether the soil into which he has transplanted Boole's ideas be congenial or not, remains to be seen.

But the most remarkable amplification of Boole's conceptions which the author has hitherto met with is contained in a recent paper by Mr. C. S. Peirce, on the "Logic of Relatives" (Memoirs of the American Academy, vol. ix.). Mr. Peirce divides logical terms into three grand classes. "The first embraces those whose logical form involves only the conception of quality, and which therefore represent a thing simply, as 'a ——.' These discriminate objects in the most rudimentary way, which does not involve any consciousness of discrimination. They regard an object as it is in itself as *such* (quale); for example, as horse, tree, or man. These are *absolute terms*. The second class embraces terms whose logical form involves the conception of relation, and which require the addition of another term to complete the denotation. These discriminate objects with a distinct consciousness of discrimination. They regard an object as over against another, that is, as relative; as father of, lover of, or servant of. These are *simple relative terms*. The third class embraces terms whose logical form involves the conception of bringing things into relation, and which require the addition of more than one term to complete the denotation. They discriminate, not only with consciousness of discrimination, but with consciousness of its origin. They regard an object as medium or third between two others; that is, as conjugative, as given of —— to ——, or buyer of —— for —— from ——. These may be termed *conjugative terms*." "Boole's logical algebra," says Mr. Peirce, "has such singular beauty, so far as it goes, that it is interesting to inquire whether it cannot be extended over the whole realm of formal logic, instead of being restricted to that simplest and least useful part of the subject, the logic of absolute terms, which, when he wrote, was the only formal logic known." The object of Mr. Peirce's paper is to show that this extension is possible. Some account was given of the notation and processes employed.

On Musical Intervals. *By* WILLIAM SPOTTISWOODE, *M.A., F.R.S.*

On Linear Differential Equations. By W. H. L. RUSSELL, *F.R.S.*

The object of this paper was to explain certain discoveries made by the author in linear differential equations, and chiefly to solve the general equation of the nth order, whenever that solution is of the form $y=P\epsilon^{\omega}$, P and ω being rational and entire functions of (x).

On a Numerical Theorem, with practical applications. By W. H. WALENN.

This novel and practical theorem is, "That if t be the tens', and u the units' digit of a two-figure number, and δ be any integer less than 10, then

$$(10-\delta)t+u$$

has the same remainder to δ as $10t+u$."

For $(10-\delta)t+u$, when expanded by multiplication, becomes $10t-\delta t+u$, or $(10t+u)-\delta t$; this latter expression only differs from $10t+u$ by an exact number of times δ, and therefore has the same remainder to δ as $10t+u$.

When this theorem is adapted to other than two-figure numbers, the expression $(10-\delta)t+u$, by expansion, becomes

$$(10-\delta)^{n-1}a+(10-\delta)^{n-2}b+(10-\delta)^{n-3}c+\ldots\ldots+(10-\delta)^2s+(10-\delta)t+u,$$

if $n=$ the number of digits or figures in the given number; for each time 10 occurs as a factor in any term, it must be treated in the way above indicated.

The remainder to any digit may be determined by means of the expression $(10-\delta)t+u$ without the knowledge of any multiple of that digit. When the arithmetical operation indicated by the formula $(10-\delta)t+u$ is resorted to, however large the number may be that is operated upon, the said operation is repeated until only one digit remains, thus yielding the remainder to δ without the performance of any division. When $\delta=9$ the operation consists merely of the addition of the digits of the given number, reducing the result from time to time to a single figure as may be requisite, also by addition; for other values of δ less than 9, multiplication as well as addition is necessary. The name *unitation* has been given to this class of operations, the remainders being *unitates*, and the divisor (δ) the *base*.

Operations upon remainders being analogous to operations (of the same kind) upon dividends, an operation (unitation) in which the base has any value less than 10 (and certain values above 10) becomes available to verify arithmetical operations. Also the unitate of an unknown number may be calculated from a known number with which it is connected by certain known operations.

The following remarks will facilitate the practical use of the operations comprised under the above-mentioned formulæ, and will illustrate and suggest applications of the theorem that might otherwise remain dormant:—

The general form of the notation to indicate the unitate of a number (x) to the base δ, is $U_{\delta}x=y$, in which y is necessarily equal to or less than δ. As U_9x is the simplest series of unitates that are useful, the suffix is left out, thus Ux.

Example:

$$x=28(25^2-2^5)=16604,\quad Ux=U1(4-5)=U(13-5)=8;\ \text{also } U16604=8.$$

$$U_7x=U\ 7(U_74^2-U_72^5)=U_77(9-4)=7;\ \text{also } U_716604=7.$$

Formulæ involving direct operations in decimals may be checked in the same way as other formulæ.

Example:

$$x=(2{\cdot}8-{\cdot}54)(51{\cdot}5+{\cdot}5^2-{\cdot}7^3)=116{\cdot}17982.$$

$$Ux=U(10-9)(2+U5^2-U7^3)=U1(2+7-1)=8.$$

Formulæ involving indirect operations, whether of decimals or otherwise, must have the remainders of division or other terminations of the process taken fully into account.

Example:

$$x=\frac{35}{17}=2{\cdot}00588\frac{4}{17},\quad Ux=U\frac{8}{8}=1;$$

also

$$U\left(2\cdot00588+\frac{4}{17}\right)=U\left(5+\frac{4}{8}\right)=U\frac{44}{8}=1.$$

Series of unitates have remarkable properties which fit them for practical use in the verification of tables &c. Recurrence is a general and most valuable rule with all series of unitates, and singular sequences are common. The series (to the base 9) for the squares is 1, 4, 9, 7, 7, 9, 4, 1, 9; 1, 4, 9, &c. By means of the series for negative powers the unitates that correspond to certain circulating decimals may be assigned; for instance, $\frac{1}{7}=\cdot142857$, 14, &c. has its unitate (to the base 9) equal to 4, $\frac{1}{19}$ has its unitate equal to 1, and so on.

The expression $(10-\delta)t+u$ also furnishes the means of obtaining unitates to bases greater than 10, such as 11, 12, 99, 999, &c. For instance, by operating with alternate digits, $U_{99}6053=U_{99}113=14$.

If the unitates (to various bases) of a number be given, it is possible to find the number; if δ be less than 10, the number of unitates required for the purpose will (at least) be equal to the number of digits in the desired number. For instance, required the two-figure number whose unitate to the base 9 is 5 and to the base 10, 4; this is found, by comparing the unitates of two-figure numbers to the said bases, to be 14.

Checking calculations, verifying tables, and ascertaining remainders to divisors are therefore accomplished with ease by means of unitation.

General Physics.

On Hills and Dales. *By* J. Clerk Maxwell, *LL.D., F.R.SS. L. & E.*

After defining level surfaces and contour-lines on the earth's surface, the author showed that the only measure of the height of a mountain which is mathematically consistent with itself is found by considering the work done in ascending the mountain from a standard station.

By considering a level surface, such as that of the sea, which is supposed gradually to rise by the addition of water from the level of the deepest sea-*bottom* to the *tops* of the highest mountains, he showed that at first there is but one wet region round the deepest bottom. Afterwards other wet regions appear at other bottom points of the surface and continually enlarge. For every new wet region there is a bottom; and when two wet regions coalesce into one there is a point where the surface is level, but neither a top nor a bottom, and this may be called a *Bar*. When a wet region, as the water rises, throws out arms and embraces within it a dry region, there is another level point which may be called a *Pass*. The wet region then becomes cyclic. When the water covers the top of the island thus formed the wet region loses its cyclosis again, and at last, when all the tops are covered, the wet region extends over the whole globe. Hençe the number of mountain-tops is equal to the number of passes plus one, and the number of bottoms is equal to the number of bars plus one.

The author then considered lines of slope which are normal to the contour-lines. In general a line of slope is terminated by a top on the one side and by a bottom on the other. At a pass or a bar, however, there is a singularity. Two lines of slope can be drawn through this stationary point; one of these is terminated by two tops and is a line of watershed, the other is terminated by two bottoms and is a line of watercourse. The watershed intersects the watercourse at right angles.

If we consider all the watersheds which meet at the same mountain-top, each of these will reach a pass or a bar. The watercourses, which also pass through these points, form a closed boundary, which is that of the region occupied by all the lines of slope which meet at the mountain-top. This region round the mountain is called a Hill.

In the same way there is a system of watersheds forming the boundary of a region called a Dale, within which all the lines of slope run to the same bottom.

The whole surface of the earth may be divided into Hills, the number of these being the same as that of their Tops.

By an independent division, the whole surface may be divided into Dales, each Dale having a different Bottom.

Besides this, we may, by superposing these divisions, consider the earth as divided into Slopes, each slope being bounded by two watersheds and two water-courses, and being named from the top and the bottom between which all its lines of slope run.

The number of Slopes is shown to be equal to the total number of Tops, Bottoms, Passes, and Bars minus two.

An Investigation of the Mathematical Theory of Combined Streams. By W. J. Macquorn Rankine, *C.E., LL.D., F.R.SS. L. & E.**

The object of the investigation, of which this is an abstract, is to extend to combinations of any number of streams of fluid, whether liquid, vaporous, or gaseous, the principles which have been applied to combinations of two streams by previous authors, and especially by Professor Zeuner, in his treatise entitled "Das Locomotivenblasrohr" (Zürich, 1863). Several component streams of fluid, each coming through its own supply-tube and nozzle, are led in directions parallel to each other into one end of a cylindrical space called the junction-chamber, in which they mingle so as to form a resultant stream; and that resultant stream escapes from the other end of the junction-chamber through an orifice called the throat. The dynamical principle upon which the motion depends is that of the equality of impulse and momentum. The aggregate momentum per second of the component streams is found by multiplying the mass of fluid which comes from each nozzle in a second by its velocity, and adding together the products. The momentum of the resultant stream is the product of the mass of fluid discharged from the throat in a second, into the velocity at the throat. The difference of these two momenta is equal to the impulse per second exerted in the junction-chamber, which impulse is found by multiplying the area of the throat by the difference between the intensities of the pressure at the nozzle-end and at the throat-end of the chamber respectively. If there is a gain of momentum, the pressure at the throat is less than at the nozzles; if there is a loss of momentum, the pressure at the throat is greater than at the nozzles.

There is always a loss of energy, which is expended in producing eddies, unless the velocities of the component and resultant streams are equal to each other. The amount of that loss can be calculated in any given case by the help of the principle already stated; and that principle being expressed in the form of an equation, and taken together with another equation expressing the equality of the mass discharged at the throat to the sum of the masses which come through the nozzles, affords the means of solving various problems as to combined streams.

On the Thermodynamic Acceleration and Retardation of Streams. By W. J. Macquorn Rankine, *C.E., LL.D., F.R.SS. L. & E.*†

The object of this paper is to state in a more general and comprehensive form than has hitherto been done to my knowledge, a thermodynamic and hydrodynamic principle of which many particular cases are well known and understood. That principle may be stated as follows:—

In a steady stream of any fluid, the abstraction of heat at and near places of minimum pressure, and the addition of heat at and near places of maximum pressure, tend to produce acceleration; the addition of heat at and near places of minimum pressure, and the abstraction of heat at and near places of maximum pressure, tend to produce

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† Printed in full in the Philosophical Magazine for October 1870.

retardation; and in a circulating stream the quantity of energy of flow gained or lost in each complete circuit is equal to the quantity of energy lost or gained in the form of heat; and in the absence of friction, the ratios borne by that quantity to the heat added and the heat abstracted (of which it is the difference) are regulated by the absolute temperatures at which heat is added and abstracted, agreeably to the second law of thermodynamics.

Amongst particular cases of the thermodynamic acceleration and retardation of streams, the following may be specified.

Acceleration by the addition of heat at and near a place of maximum pressure:—the draught of a furnace; and the production of disturbances in the atmosphere in regions where the ground is hotter than the air.

Retardation by the abstraction of heat at and near a place of maximum pressure:—the dying away of atmospheric disturbances in regions where the ground is colder than the air.

Acceleration by the abstraction of heat at and near a place of minimum pressure:—the injector for feeding boilers, in which a jet of steam, being liquefied by the abstraction of heat, is enabled not only to force its way back into the boiler, but to sweep a current of additional water along with it; also, to a certain extent, the ejector-condenser.

The conduction of heat from the parts of a stream where the pressure and temperature are highest to the parts of the same stream where the pressure and temperature are lowest, produces, according to the foregoing principles, a gradual and permanent retardation of the stream, independently of the agency of friction; and this is accompanied by the production of heat to an amount equivalent to the lost energy of flow.

Report of the Liverpool Compass Committee. By JOHN T. TOWSON.

The last Report read to the British Association was in 1859, at Aberdeen. The most important result that had occurred since that time was the cessation of the difference of opinion that had previously existed between those connected with the royal navy and with the mercantile marine, the former advocating the use of a table of errors, the latter mechanical compensation on the principle introduced by the Astronomer Royal. In 1854, Mr. Towson said his advocacy of compensation was scarcely tolerated by some Members of the Association; but in 1869, Mr. Archibald Smith, one of the authors of the 'Admiralty Manual on Compass Matters,' stated before the Royal Society that the question of mechanical compensation of the compass had materially changed in its aspect of late years, and he advocates its use in most cases. The next matter was of minor importance, but proves that neither a table of errors nor mechanical compensation can be relied on within the limit of three degrees. If the ship be swung to the north or south, from left to right, the needle will be drawn three degrees more to the right than it would be if the ship were swung in the contrary direction. The most valuable result which has been brought about within the last year is the establishment of a voluntary examination of masters of iron ships in the theory and practice of compass-deviation.

On Non-tidal Variations of the Sea-level on the Coast of India. By W. PARKES.

This paper gave some results based on tidal observations taken at Kurrachee, near the mouth of the Indus. It described a graphical process for eliminating the changes of sea-level due to semidiurnal and diurnal undulations, thus exhibiting only those which are due to tides of long period or other causes. Referring to the diagram for the month of November 1868, which is appended to the Report of the Tidal Committee in this volume, it will be seen that the black dots representing the successive heights of high and low water range themselves in four waving lines along the paper. The line which represents "half-tide level" was so drawn as to be the locus of a series of ordinates, each of which is a mean of the corresponding ordinates of these four lines.

By measuring off the ordinate (or height above a fixed level) for noon of each

day, 365 values of half-tide level were obtained for the year, varying from 25 inches above the mean to 10 inches below, or to a total extent of 35 inches. These 365 values were tabulated and grouped successively as follows:—

1st. The averages for the calendar months respectively were obtained. These do not indicate any sensible annual or semiannual tide.

2nd. The same figures were next grouped according to the lunations, so as to obtain the mean height for every day of the moon's age. The figures showed that there was no sensible tide following these periods.

3rd. Next they were grouped according to the declination, so as to obtain the mean height on the days when the moon was crossing the equator from north to south, and on each successive day till she returned to the same position. From this it appeared that the water was slightly higher when the moon was in north than when she was in south declination; and a similar result was obtained by treating the values for the year 1867 in the same manner, but the difference ($1\frac{1}{2}$ to 2 inches) was too small to justify any conclusion.

4th. They were then grouped according to the moon's distance from the earth. The means for 1868–69 showed a slight elevation when the moon was near apogee, and a depression when near perigee; but this result was not confirmed for 1867.

From these trials it was concluded that there were no sensible tides of long period due to solar or lunar influence, and that the causes of the variations must be sought for elsewhere. So far, however, the result has been only negative. The range was too great to be attributed to atmospheric pressure, and the want of any persistent elevation during the south-west monsoon showed that they could not be attributed (directly, at least) to local winds.

An extraordinary rise took place in June 1869 to the extent, when at the maximum, of 25 inches. The sea-level was unusually high for about seven days, during which there was great heat and an unsettled appearance in the weather, but no definite atmospheric disturbance. A similar effect was observed at about the same period in 1868, but not in 1870.

Astronomy.

On the Present State of the Question relative to Lunar Activity or Quiescence. By W. R. Birt, *F.R.A.S.*

From the time of Schröter the question of change on the moon's surface has been more or less agitated; the 'Selenotopographische Fragmente' contain numerous instances of what he considered to be changes of a temporary character, and a few of a more permanent nature, as the formation of new craters. It is, however, notorious that he failed to establish the fact of a decided change in any one instance; nor is this to be wondered at when we consider the paucity of the materials he had at his command. Notwithstanding the comparative neglect into which the observations recorded in the 'Fragments' have fallen and the judgment passed upon them by some of the best known selenographers, there can be no question that they embody the results of zealous and persevering attention to the moon's surface, and ought not to be passed over in the examination of any given spot the history of which we are desirous of becoming aquainted with *during the earliest period of descriptive observational selenography.*

The labours of Schröter's successors, Lohrmann and Beer and Mädler, have added greatly to the number of objects, either as delineated on their maps or referred to in their letterpress. Lohrmann appears to have carefully studied Schröter's results, as we find him quoting the measures obtained by Schröter in several instances. On examining the results of the two greatest selenographical works of the present century and comparing the one with the other, we find precisely the same kind of phenomena presenting themselves, which in a great measure perplexed Schröter; but as Lohrmann and Mädler worked independently of each other, and Mädler evidently had a very low idea of the value of the preceding labours of Schröter, these phenomena passed unnoticed at the time. Upon consult-

ing the three works for elucidating the history of any given object, such results as these are frequently obtained. An object is found in Schröter designated by a Greek or other character, and its appearance described in his text. This object may be altogether omitted by Lohrmann, but given on Beer and Mädler's map; and objects are by no means rare which may be found on Lohrmann, but omitted by Beer and Mädler, and *vice versâ*.

Were the results of the labours of Julius Schmidt during a period of nearly thirty years given to the public, there can be no doubt that our knowledge of selenography would be greatly advanced. His chart must contain a large proportion of the objects previously recorded by Schröter, Lohrmann, and Beer and Mädler; and, judging from the instances already alluded to, of *apparent omissions* by one or other of the above-named observers, it is highly probable that the number of such instances would be much increased. The value of his measures (4000) of the altitudes of lunar mountains for comparison with or addition to those of Schröter and Mädler cannot admit of a doubt. His published catalogue of rills is very valuable in this respect. It is to Schmidt that we are indebted for one of the most important announcements bearing on the subject of lunar activity, that of a change in the crater *Linné*, "which," says Mädler (Report Brit. Assoc. 1868, p. 517), "has hitherto offered the only authentic example of an admitted change." He had previously said (same Report), "what has lately been observed in the crater *Linné* proves at all events that *there* real changes have taken place, and *that* too under circumstances even visible to us." Further on, however, the great selenographer remarks that on the 10th of May, 1867, his eye having undergone an operation for cataract, he attempted an observation of *Linné* in the heliometer of the observatory at Bonn, and found it shaped exactly, and with the same throw of shadow, as he remembered to have seen it in 1831. "The event," he says, "of whatever nature it might have been, must have passed away without leaving any trace observable by me." The doubt still hanging over this object is well known, and it may be regarded as furnishing at least one of the instances of the present state of the question of activity. The uncertainty attaching to the question of change in this particular instance mainly arises from the difficulty of deciding upon the accuracy or otherwise of the delineations of Lohrmann and Beer and Mädler, although both describe it as showing a diameter of five or six English miles. Generally speaking, the observations between October 1866 and July 1870 all agree in its present appearance, differing greatly from that which it must have presented according to the delineations and descriptions of the two selenographers just named; also that no change of a physical character has taken place in it during the $3\frac{3}{4}$ years it has been under constant observation.

It has been supposed that photography would solve all such difficulties, and that photograms of the lunar surface taken under similar angles of illumination and visual ray would agree with each other; but here, again, precisely the same difficulties present themselves which perplexed Schröter, and which have been met with in comparing Lohrmann's and Beer and Mädler's works. Objects figured by the earlier selenographers occur on some photograms, but not on others of about the same phase of illumination. There appears to be an agency capable of affecting the visibility of objects, rendering them indistinct or invisible on some occasions, while on others they are distinctly seen on the photograms. Whatever operations may have taken place in the crater *Linné*, producing phenomena the recurrence of which is *rare*, in all the examples above mentioned, from Schröter's time to the present we have phenomena of a different character, exceedingly difficult of explanation, and constituting an important element in the solution of the question of present activity or quiescence; for unless it be fully proved that *all* these instances depend upon changes of visual and illuminating angles, a strong suspicion will exist of their being more immediately connected with the moon itself. To effect such a proof, however, is a matter of no small difficulty. Mädler alludes to the performance of calculations of the most varied kind as necessary for the delineation of lunar features; and in the case before us the calculation of several elements for *each separate observation* (and they are very numerous) is absolutely essential for the purpose of referring the phenomena observed to changes of illumination and visual ray. Calculations of this kind have not yet been made to any great extent,

and the consequence is that the entire question remains involved in doubt. During the last seventeen months as many as 1227 observations of the spots on *Plato* alone have been made; and although the varying state of the earth's atmosphere affects in no slight degree the visibility of such delicate objects, phenomena are presenting themselves which call for a much more rigorous treatment than has yet been accorded to them. The affirmation of change on, or quiescence of, the moon's surface must depend, not upon the accumulation of desultory and undiscussed observations, but upon such as are undertaken on a well-arranged system and discussed with reference to every known agency capable of affecting them. The present state of the question is therefore one of *doubt*, one that calls for observation of the most vigorous character and discussion of the most rigorous nature to settle it. Observation of late has been tending towards a registration of minute detail detected on the moon's surface, but discussion in various ways is behind the requirements of selenography, and until it can keep pace with observation the doubt alluded to above must remain.

On the Distribution of Cometic Perihelia. *By* A. S. Davis, *B.A.*

The hypothesis that those comets whose orbits are undistinguishable from parabolas are moving in hyperbolic, non-periodic orbits, leads to the following theoretical law for the distribution of their perihelia. The number of comets within any distance from the sun is proportional to that distance. This follows from an investigation contained in a paper on cometary orbits published in the Philosophical Magazine for September 1870. The first object of the present paper was to show that the actual distribution of the perihelia of parabolic and hyperbolic comets is probably in accordance with this law. For this purpose the numbers of comets having perihelion distances lying respectively between 0·0 and 0·1, between 0·1 and 0·2, and so on, were ascertained. It was found that, instead of these numbers being nearly equal, they were respectively 11, 10, 14, 17, 11, 33, 18, 23, 21, 24, 15, 10, 8, 4, 5, 1, 1. It was then shown that this want of agreement with the theoretical law of distribution might arise from the fact that the probability that a comet will be observed depends upon the magnitude of its perihelion distance, those comets being most likely to be observed which have perihelion distances rather less than the radius of the earth's orbit. That this cause does produce a considerable effect upon the apparent manner of distribution of perihelia was shown thus:—The known comets were arranged in three groups containing respectively those which appeared before 1750, between 1750 and 1800, and between 1800 and 1865. The numbers representing the distribution of perihelia for these three groups were respectively

1, 3, 2, 8, 3, 16, 4, 7, 3, 6, 2, &c.,
4, 2, 6, 3, 7, 7, 7, 10, 6, 7, 5, 2, 1, &c.,
6, 5, 6, 6, 1, 10, 7, 6, 12, 11, 8, 8, 7, 4, &c.,

showing that the distribution of the perihelia of a later group are much more nearly in accordance with the theoretical law than that of an earlier group, owing doubtless to the fact that the probability that a comet would be detected was formerly more dependent upon the magnitude of its perihelion distance than it now is. It seems probable that if all the comets which visit the sun were observed, the distribution of their perihelia would be nearly in accordance with the above-stated theoretical law. Such an accordance the author thought would be an argument in favour of the theory that the parabolic comets are non-periodic.

In the second part of the paper the author showed that a statement made by Prof. Kirkwood regarding the distribution of cometic perihelia was incorrect. Prof. Kirkwood, on finding that the longitudes of the perihelia of a large proportion of those comets with very small perihelion distances do not differ greatly from the longitude of the solar apex, concluded that this fact was due to a crowding of the perihelia about the solar apex, produced, he thought, by the sun's motion in space. Prof. Kirkwood had not shown that the latitudes of the perihelia were nearly the same as the latitude of the solar apex. The author found, by marking upon a celestial globe the positions of the perihelia of all parabolic and hyperbolic comets with

perihelion distances less than ·5, that the perihelia of comets with very small perihelion distances exhibit no greater tendency to crowd about the solar apex than comets with larger perihelion distances.

On Solar Spots observed during the past Eleven Years. By the Rev. Frederick Howlett, *F.R.A.S.*

The paper was illustrated by numerous very carefully executed drawings, enlarged from others which had been micrometrically observed and drawn at the telescope, chiefly by means of projecting the sun's image on a screen. It was well known how rich the years 1859 and 1860 were in solar spots; and the eleven-year period was again being strikingly corroborated by the number and size of the groups and individual spots of the present year, and which may be expected to prevail until 1871. Magnificent groups which appeared in the sun's northern hemisphere in March, April, and August, in almost precisely the same heliographic latitude and longitude, would apparently seem to evince that the disturbing causes, whatever they were, had localized themselves on the disk—not, however, without long intervals of comparative repose. The forms assumed by the faculæ were described by the author, who felt convinced that they were attached, for the time being, to the photosphere, and that they were not clouds floating above it; otherwise they would frequently impinge on the penumbræ in ways very different from those in which, in point of fact, they are seen to occur. If they consist of simply photospheric matter, however, it would seem to be in some *compressed* or otherwise peculiar manner; inasmuch as the *coarser* mottling, so plainly to be distinguished on all other parts of the sun's surface, can never be detected on the faculæ, and especially on those masses enclosed more or less at times within the receding margins of the penumbræ. Dr. Huggins, however, has detected the finer or *rice-grain* specks of light in some of the more diffused forms of the faculæ. There is apparently no direct relationship between the amount of solar-spot disturbance and the terrestrial magnetic storms. The author, however, has suggested the possibility of there being some degree of correlation between groups of a peculiarly cyclonic arrangement and unusual magnetic disturbances; none, or next to none, of the spots had been found to possess any tendency to rotate as it were on an axis—as has, however, been occasionally witnessed by other observers. An instance was given (illustrated by a drawing) how a diffused penumbral speck was observed to *draw in* towards the neighbouring umbra of a solar spot at the rate of 12 seconds of arc in four hours, which is equivalent to about 660 yards per second (and closely similar to observations of the same kind by Chacornac). As the speck drew in towards the umbra it assumed a continually more narrow and wedge-shaped form (the apex towards the direction of advance), and which, therefore, might well be taken to indicate that down-rush into the umbra aforesaid insisted upon by Mr. Norman Lockyer. Assuming, as the author does, that the spots are depressions in the solar photosphere, filled up by the solar gaseous atmosphere, this is evinced, 1st, by the ordinary testimony of the eye; 2ndly, by the stereoscopic effect obtained by Mr. De La Rue's photographs of spots taken at intervals of about two days; 3rdly, by the foreshortening of the penumbra of a neat circular spot, alternately on the right and left side, as it first comes on, and then passes off the disk—a phenomenon first noticed by Dr. Wilson in the last century; and 4thly, by the elegant spectro-barometric evidence (as the author termed it), whereby the progressive thickening of the dark solar absorption-lines, as they pass successively over the spectrum of the photosphere, penumbra, and umbra, seemed to prove an increasing density and depth of an absorbing solar atmosphere. It is, however, urged by Kirchhoff, Donati, and some others (and in a measure admitted by Browning) that like effects similar to those four above enumerated might be produced were the spots cloudy condensations, and not depressions. The author called attention to a delicate way (not readily to be noticed without projecting the sun's image on a screen) in which a fine trailing serpentine arrangement of minute specks of penumbral matter may be sometimes seen either following in the wake of a large spot, or meandering amidst a group of spots, indicating the resolution of two or more forces, partly, perhaps, cyclonic, and partly centrifugal, as connected with the sun's axial rotation.

On Shooting-stars. *By the* Rev. R. Main, *M.A., F.R.S., F.R.A.S.*

The author presented to the Association the observations of meteors and shooting-stars made almost exclusively by Mr. Lucas, at the Observatory, during the past year. The whole number of meteors seen and observed during the year is about 300, of which, of course, a considerable number belong to the November and August groups. Next to these, the month of October seems to be the most fruitful, while, on the contrary, in January, February, and March scarcely any were seen. This, however, may be due to the cloudy state of the sky which generally prevails at Oxford in the early part of the year. Of those observed, more than fifty were as bright or brighter than stars of the first magnitude; six were as bright as Jupiter; one, observed on November 4, 1869, was estimated as equal to one-sixth of the full moon; and one, on December 29, as equal to one quarter, the sky being overspread in the latter case by light clouds. Two remarkable meteors were seen on November 6, one of which was observed (by a person not connected with the Observatory) to burst with noise near the north-west horizon. On July 8 one was seen to burst, though the sky was so overcast with nimbus cloud that no star could be seen.

On the Laws of Star-grouping. *By* R. A. Proctor.

The aim of this paper was to show that the stars are grouped together in varied forms, separated by comparatively barren distances, and that the observed peculiarities of stellar distribution are due to real laws of aggregation and segregation.

Electricity and Magnetism.

On Faure's Battery. *By* C. Becker.

Faure's element is a modification of that known as Bunsen's, the poles consisting of carbon in strong nitric acid and amalgamated zinc in dilute sulphuric acid. In Bunsen's ordinary form of carbon element the carbon pole is immersed in a vessel holding a considerable quantity of nitric acid, which, as it becomes deoxidized by the electrolytic action of the current, liberates nitrous-acid gas, which rises into the air, rendering it unwholesome to breathe and destructive to most metallic apparatus in its neighbourhood. The purpose of Faure's battery is to obviate those drawbacks. This is effected by confining the nitric acid inside the carbon pole, and allowing only sufficient acid to percolate through it in order to keep up the necessary electrolytic action of the element. The carbon pole is made in the form of an ordinary bottle, and is provided with a carbon or platinum stopper to which the binding-screw of the pole is attached. This bottle, which at once fulfils the functions of pole and porous diaphragm, is placed concentrically in the interior of a cylinder of amalgamated zinc; and the whole is contained in an earthenware jar. When set up for action the bottle is nearly filled with nitric acid, and the space containing the zinc between the bottle and the outer jar to the required height with sulphuric acid. The slight liberation of gas within the bottle causes a sufficient pressure to be exerted upon the nitric acid to force it gradually through the carbon.

In this way the exterior of the carbon pole remains immersed in a very thin layer of nitric acid immediately opposite the zinc, which is in course of dissolution of the dilute sulphuric acid. In point of constancy the element is superior either to Bunsen's or Grove's, because the body of nitric acid remaining protected within the bottle does not become weakened as in the case with those forms of element in which the fluids are exposed in larger quantities and separated by porous diaphragms. It acts also entirely without any disengagement of gas into the air, so that it may be used in any room without disagreeable consequences. A variety of forms might no doubt be given to these elements, which would enable them to fulfil the desired object. Those exhibited were designed and manufactured by Messrs. Elliot Brothers, and are found to be convenient for experimental purposes as well as for use in telegraph offices.

On an Induction-coil, specially arranged for use in Spectrum Analysis. *By* John Browning, *F.R.A.S.*

When an induction-coil is used for the purpose of burning metals, it is necessary to interpose one or more Leyden jars in the current. Such an arrangement though efficient is inconvenient. The glass jars are liable to fracture, are bulky, and require to be dry to perform well; and the wires connecting them with the coil are in the way and liable to derangement.

To obviate these difficulties I constructed a form of apparatus which consists essentially of a flat mahogany box filled with plates of ebonite, which are coated on each side with tinfoil to within an inch of the edges. The contrivance generally used for holding the metal or containing the gas under examination is packed inside the lid of the box. When in use, this fits into a hollow screw on the top of the box. To set this apparatus in motion, it is only necessary to carry a fine wire from each of the terminals of the induction-coil and insert it in the connexions provided at each end of the box, as these are connected with the tinfoil with which the ebonite plates are coated.

Mr. Spottiswoode suggested that there should be a contrivance added, by which a greater or less number of the coated plates may be brought into action at will. This arrangement is very useful, as it enables the temperature of the spark to be regulated.

The simplest and best method of employing the coated ebonite plates, however, is to place them in the base of the induction-coil, underneath the ordinary condenser, and connect them with the terminals. When thus arranged, the dense thick spark may be obtained from any substance placed between the terminals of the coil, or in any apparatus which may be attached to them, and a great economy of time is effected.

On the Maximum amount of Magnetic Power which can be developed by a given Galvanic Battery. *By* H. Highton.

The author's object was to show that by means of any galvanic battery whatever electro-magnets might be made capable of sustaining any amount of weight without limit. It was shown, both by mathematical formulæ and experiment, that this was the case, as also that a constant weight could be sustained, while the expenditure of zinc in the battery could be at the same time continually diminished without limit. In the discussion which followed, it was pointed out that this was a mere power of sustaining weights, and not an energy such as could be applied to working an electro-magnetic engine; for that if the magnets were used to work an engine, the currents produced by the reaction would cause an increased consumption of zinc.

Letter from Dr. Joule, *F.R.S., on a New Dip-Circle.*

My dear Sir,—I communicated to the Exeter Meeting of the Association a short account of a new dip-circle, the peculiarity of which consisted in the suspension of the axis of the needle by filaments of silk, of which the extremities were hung from the arms of a delicate balance beam. I had hoped to exhibit the instrument to the Section, but have found myself unable to attend the Meeting. It may, however, be interesting to magnetic observers if I state that my experience during the year has fully borne out the superiority of the new inclinometer over the ordinary form of instrument. The facility of observation with it is such that six complete observations of the dip can be obtained in one hour, the average error of a single observation being a small fraction of a minute of arc. I am now giving still further delicacy to the instrument by substituting spider-threads for silk, and am obviating the danger of rust by using platina for the axis of the needle instead of steel, the softness of the former metal being unobjectionable since the agate-plates are dispensed with.

Believe me, yours most truly,

Professor J. C. Maxwell. James P. Joule.

On an Improved Lantern for Lecture demonstrations with Electric Light. *By* W. Ladd, *F.R.A.S.*

The body of the lantern is formed of a brass tube 9 in. diameter, in the centre of which is fixed the electric light; at two points in the tube, situated about 100° apart, are openings, to one of which is attached a flange into which the various optical arrangements slide; the other opening has a sliding piece carrying a second and similar flange, so that the various pieces of apparatus are mutually interchangeable: by pointing one of these openings direct on to a screen, the other will be in the proper position for a ray of light passing through two bisulphide-of-carbon prisms to give the spectrum on the same screen; by this arrangement the demonstration of the arc and then of the spectrum of any metal becomes one of great simplicity; for without altering the position of any part of the apparatus, and the metal still continuing to burn, you simply have to uncover the opening, which gives you the arc; then closing this and uncovering the second opening, immediately will appear the spectrum of the same substance. Attached to the body of the lantern is a very useful adjunct to the instrument, consisting of a small sliding-tube, to one end of which is fixed a piece of dark ground glass and to the other a lens; these are so adjusted that a perfect image of the carbon-points can be seen by the operator on the dark glass without opening the lantern or admitting stray light into the room; and by having a line ruled in the ground glass central with the various optical arrangements and simply watching the image there produced, the lamp can be so adjusted as to keep the light absolutely central—a desideratum every one will admit who has had to use a microscope or polariscope with the electric light. Within the lantern is fixed a small gas jet to enable the operator readily to change the carbon-points, &c.

The shifting-motion of the flange is, for the purpose of adjusting the angle of the openings, to suit the different distances of the lantern from the screen; and as one lantern is all that is required, there is very little obstruction to the view.

On a New Absolute Electrometer. *By* Professor Sir William Thomson, *M.A., LL.D., F.R.S.*

On a new Field of Magnetic Research. *By* Frederick H. Varley, *F.R.A.S.*

A permanent magnet was exhibited, which displayed the action of magnetism upon the crystallization of iron. The author referred to this fact as affording a means for the future investigation of magnetic phenomena, and also showed that diamagnetic substances could be crystallized in magnetic fields, and thus would define permanently the action of magnetism on the crystallization of magnetic and diamagnetic metals. He expressed his belief that, from experiments commenced in the year 1858 and others conducted in 1870, electricity and magnetism conjoined would produce permanent magnetic structures, showing in a solid form the lines and nature of magnetic force.

On a Constant Battery. *By* Frederick H. Varley, *F.R.A.S.*

The author exhibited a new form of battery, designed by Mr. Octavius Varley, for the purpose of removing the defects of the otherwise constant battery of the late Professor Daniell. In this form of battery the porous chamber, which has been the source of all the trouble, is removed. The battery comprises a water-tight compartment for the copper-salt, a connecting column of fluid, and a compartment for the zinc-salt. These are so arranged that, whilst the electro-chemical continuity is completed at the top of the copper-chamber, no intermixture of the salts can take place; convection-currents, which are the great source of intermixture, are divided into three separate systems, which cannot possibly interfere one with another. Whilst economy of the copper-salt is effected, greater uniformity and higher potential is maintained. The zinc plate is found to work out to the very last, being kept free from the coating of copper to which all batteries hitherto constructed are liable.

A Magnetic Paradox. *By* S. Alfred Varley, *Assoc. Inst. C.E.*

The author stated that the instrument which had been called a magnetic paradox (because the phenomenon it presented was the apparent repulsion of iron by a magnet) consisted of a compound magnet in a box, and when pieces of iron were placed over the poles on the box they became magnetic by induction, and were attracted by the magnet; but if a bar of soft iron, not in itself magnetic, were approached near to the pieces of iron, the pieces of iron leap away from the box and become attached to the soft iron bar. The effect produced was stated to be due to the fact that magnetic force was transmitted by induction; when the soft iron bar was approached to the pieces of iron, the magnetic forces resident in them, which had been separated and rendered active by the magnet on the box, developed the magnetic forces resident in the soft iron bar, and consequently it followed (the resistance which soft iron opposes to magnetic polarization being so small that it may be here disregarded) that as the dual forces resident in iron are equal (and the one force cannot be called into being without equally developing the other) when the bar is approached nearer to the pieces of iron than the poles of the magnet, they are attracted away from the box by the superior attraction exerted by the soft iron bar. It was shown that when pieces of iron were placed direct upon the poles of the magnet, they could be removed by the superior attraction of the soft iron bar over that of the magnet; the explanation of this effect was stated to be the iron bar collected the lines of magnetic force issuing from the magnets, and the magnetism developed in the iron bar was more localized than in the magnetized bars composing the magnet in the box.

A Description of the Electric Time-Signal at Port Elizabeth, Cape of Good Hope. *By* S. Alfred Varley, *Assoc. Inst. C.E.*

The author having described the general arrangements connected with the Liverpool time-ball, of which he had the charge at the time of its erection, the methods he adopted for measuring the time which elapsed between the current leaving Greenwich and the falling of the ball at Liverpool, and the means employed for checking the working the apparatus in the telegraph offices, he stated the time which elapsed between the arrival of the time-current in London and the falling of the ball at Liverpool was $\frac{11}{20}$ of a second; $\frac{5}{20}$ of this interval of time was occupied by the electric current travelling through an underground circuit from London to Liverpool, and $\frac{6}{20}$ in discharging the apparatus at London and Liverpool. In 1859, Sir Thomas Maclear, the Astronomer Royal at the Cape of Good Hope, inspected the electrical time-signals in this country, with a view of erecting time-balls in connexion with the Royal Observatory at Cape Town, and this led the author afterwards to design at different times two time-triggers for use in the Cape. In September 1864 the author was requested to construct a trigger for discharging a time-ball to be erected at Port Elizabeth; and as he considered the intervention of any relay or secondary apparatus to be objectionable, he determined, if possible, to construct the trigger sensitive enough to be discharged by the batteries in the Cape Town Observatory; and in its construction he adopted a modification of a principle first introduced by Professor Hughes in his printing telegraph (described at the Newcastle Meeting). The trigger was constructed with a soft iron armature rendered magnetic by induction from a compound bar magnet, and the armature strongly attracted the soft iron cores of an electromagnet, but was prevented from actually touching the poles of the electromagnet. A spiral spring attached to this armature was so adjusted that it nearly overcame the magnetic attraction induced by the bar magnet. The time-current polarized the electromagnet in the opposite direction to that induced by the bar magnets; and as the attraction between the armature and the soft iron cores was already almost overcome by the spiral spring, a very small amount of polarization in the opposite direction was necessary to release the armature which was rapidly pulled away by the spring, and the trigger discharged. The rapidity of discharge with this trigger was very great; $\frac{1}{20}$ part of a second only elapsed between the arrival of the time-current and the falling of the ball. From a report in the Port Elizabeth paper of August 29, 1865, giving an account of the inauguration of this time-signal, and forwarded to the author by

Sir Thomas Maclear, it appears that the time elapsing between the time-current leaving the Observatory at Cape Town and the receipt at Cape Town of the signal announcing the falling of the ball is only $\frac{1}{15}$ of a second. What is being daily done in the Cape can, however, be best summed up by a short quotation from a letter received from Sir Thomas Maclear, giving an account of the successful inauguration of this signal. After detailing the general arrangements, Sir Thomas goes on to state:—

"A few tentative signals having proved satisfactory, the 'preface' was issued from the Observatory at ten minutes before one o'clock, and at the instant of one o'clock the Observatory time-ball clock closed the circuit, discharging the Observatory ball, the Simon Town ball, twenty-four miles distant, the Cape Town time gun, three miles distant, and the Port Elizabeth ball, distant 500 miles."

On the Mode of Action of Lightning on Telegraphs, and on a New Method of constructing Telegraph-coils. By S. ALFRED VARLEY, *Assoc. Inst. C.E.*

The author stated that in the early days of electric telegraphy lightning-protectors were used to protect the coil-wires in telegraph offices; the general type of the protector adopted was an insulated pointed conductor connected to the line-wire, and in close proximity to a metallic conductor leading to the earth. At a subsequent date the use of lightning-protectors in telegraph offices was practically abandoned, as they were found not to prevent the fusion of the coil-wires, or only exceptionally; for although the lightning would leap across the space of air separating the insulated conductor from the earth-conductor, an electrical discharge also passed through the coils and frequently fused them.

When lightning-storms occur in the neighbourhood of telegraph-wires, although the wires may not be actually struck, powerful currents are induced in the wires; these currents may in some cases be sufficiently strong to fuse the instrument coils, but they more frequently simply demagnetize, and as often reverse the magnetism of the magnetic needles which are situated in the coils of needle-telegraph instruments.

Needle telegraphs are largely used on railways for train signalling, and the demagnetization or the reversal of the magnetism in these instruments is very serious, as the safety of the train depends in a great degree upon the correct working of the signalling instruments. In 1866 the author introduced instruments which he considers to fulfil in a great degree the conditions to be desired in needle telegraphs. In these instruments the case, the bearings, and the blocks which limit the motion of the handle are made of cast iron in one solid piece, so there are no parts to be shaken loose by rough usage. The magnetic needles inside the coils, instead of being made of tempered steel magnetized, are made of soft iron, and are rendered magnetic by induction from permanent magnets in the neighbourhood of the coils; and as they are magnetic only by virtue of the permanent magnets in their proximity, the influence of powerful currents induced by lightning can only be momentary.

The coils are protected from fusion by means of a novel protector termed a "lightning-bridge," as it forms a bridge for high tension electricity to pass over. It was well known that high tension electricity would leap across a small space of air in preference to passing throughout the length of a coil of wire; and it was stated this arose from the momentary resistance the wire opposes to polarization or magnetization,—a resistance probably approaching to infinite resistance during an infinitely small interval of time; and from this cause, even in a vacuum protector, where the pointed conductors are enclosed in an exhausted chamber, the main discharge will leap across a space of air separating the insulated conductor and the earth conductor outside the exhausted chamber. The author, when experimenting with electric currents of varying degrees of tension, observed the very great resistance which a loose mass of powder of conducting matter opposed to the passage of electricity of moderate tension; he found with a tension of 50 Daniell cells electricity did not pass through a loose mass of finely divided black-lead or wood charcoal. When the tension was increased to two or three hundred cells, the particles arranged themselves by electrical attraction, making good elec-

trical contact, and formed a bridge by which the electricity freely passed. With a tension of six or seven hundred cells the electricity was found to pass through a considerable interval of the dust met with in rooms, which consists chiefly of silica and alumina, with more or less organic and earthy matters.

Incandescent matter offers a very free passage to electricity; masses of highly heated blacklead-powder were found with six cells to give an average resistance of four units, and wood-charcoal powder an average resistance of five units, or about $\frac{1}{60}$ of that opposed by an ordinary needle-telegraph coil, which may be taken at 300 units. These experiments went to show that an interval of dust separating two conductors oppose practically a decreasing resistance to an increasing tension, and led to the construction of the "lightning-bridge," which consists of two pointed conductors enclosed in a chamber, and approached to within $\frac{1}{18}$ of an inch from one another, and surrounded with finely divided matter consisting of carbon and a non-conducting substance intimately mixed. The reason why a powder consisting entirely of conducting matter cannot be safely employed is, that although it opposes a practically infinite resistance to the passage of electricity of the tension of ordinary working currents, when a high tension discharge occurs the particles under the influence of the discharge generally arrange themselves so closely as to make a conducting connexion between the two points of the lightning-bridge. If the effect of lightning striking the wires be considered, it will be seen that the electric discharge passing through the telegraph-coils is not momentary, but occupies time.

When an insulated telegraph-wire is struck, the effect of the electric discharge is to polarize the wire throughout; after the discharge the wire returns to its normal unpolarized condition; but the cessation of magnetization, although rapid is not instantaneous, and the effect of the wire assuming its normal unmagnetic condition will be to develope an electric current flowing in the same direction as the electric discharge which magnetized the wire. The tension of the current developed by the demagnetization will be very high at its first development, and will rapidly afterwards fall to zero; there is therefore, first, the main discharge of electricity which passes by the shortest route, and does not wait to polarize the coil-wires, but leaps across a space of air to the earth conductor as the easier course, followed by a secondary current in the same direction but occupying time. The tension of this secondary current, although at first very high, is not nearly so great as the lightning discharge, and the greater portion, if not the whole, will pass through the coils, which oppose, when time is given, a much lesser resistance than the smallest possible space of air; it would therefore seem, when telegraph circuits protected by the ordinary protector are struck by lightning, it is to the secondary current, and not to the main discharge the fusion must be attributed. The fact that the coils of needle telegraphs are more often fused than other telegraphic apparatus was considered to be a strong confirmation that the fusion was due to the secondary current developed by the demagnetization.

The relay coils used in other telegraph systems have soft iron cores which are rendered magnetic when a current is passing through the coils. A greater amount of magnetism is developed in the cores than in needle-telegraph coils; but a very sensible time is occupied by the iron passing from the normal to a magnetized condition. The momentary resistance these cores oppose to magnetization is very great; the demagnetization of the line-wire proceeds more slowly; the electricity generated by the demagnetization being of a definite amount, the tension of the secondary current is reduced proportionately. The line-wire of a telegraph circuit is only a continuation of the coil-wires, and is rendered magnetic by electric polarization in the same way as the coils, the chief difference being that the magnetism developed in the coils is concentrated in a smaller space. When lightning strikes the line-wire of a circuit in which electromagnets are used, and having an ordinary protector, it magnetizes the line-wire, leaps the space separating the points of the protector, and does not magnetize the electromagnets; demagnetization of the line-wire which always takes time, and which can be retarded, follows, and the resistance which the soft iron cores oppose to the assumption of magnetization retards the demagnetization of the line-wire, reducing the tension of the secondary current. In needle-telegraph coils, there being no large mass of iron to be magnetized,

demagnetization of the line-wire follows much more rapidly, the secondary current is more intense, and consequently these coils more often suffer.

When a circuit protected by the "lightning-bridge" is struck, the lightning finds in its direct path not a space of air, but a bridge of conducting particles in very close proximity to one another; it connects these under the influence of the discharge, and renders the particles highly incandescent. Incandescent matter, as already demonstrated, offers a very free passage to electricity, and the secondary current finds an easier passage across the heated matter than through the coils. These lightning-bridges have been in use more than four years; there are upwards of 1000 doing duty in this country alone, and not a single case has occurred of a coil being fused when protected by them.

Four years have elapsed since the introduction by the author of induced magnetic needles for needle telegraphs; there are some thousands of them now doing daily work. The coils of the old pattern are being converted into induced magnet coils, and it is probable that induced magnet coils will entirely supersede the so-called permanent magnets used in needle-telegraph instruments.

Meteorology.

Rainfall—its Variation with Elevation of the Gauge. *By* Charles Chambers, *F.R.S.*

The fact is well known to meteorologists that the quantities of rain received in gauges placed at different heights above the ground diminish as the elevation of the gauge increases. Several attempts have been made to explain this phenomenon, but none of them are so satisfactory as to discourage the search for other causes that may contribute substantially or mainly to its production. Hence the submission for the consideration of the British Association of this further attempt.

One of the principal causes of rain is undoubtedly the transfer, effected by winds, of air charged with moisture in a warm damp district to a colder region, where the vapour it contains is partially condensed. The temperature of the lower as well as of the higher horizontal strata of the atmosphere being reduced by this transfer, it may fairly be inferred that condensation of vapour may also occur in the lower as well as the higher strata. The rain caught by a gauge at any given elevation will therefore be the sum of the condensations in all the strata above it, and thus the lower a gauge be placed, the greater will be the quantity of rain received by it.

Again, it is known by observation that there is at all times a greater or less difference of electrical tension between the atmosphere and the surface of the ground. If, then (in accordance with the views of Prof. Andrews as to the continuity of the liquid and gaseous states of matter, from which it follows that the changes of other physical properties must also be continuous), we regard the particles of vapour suspended in the air as electric bodies in relation to the dielectric principal constituents of the atmosphere, they will be polarized by induction from the electricity of the ground. This polarization will give rise to an attraction between every particle and the neighbouring particles above and below it; and being stronger in the particles nearer the ground than in those more remote, the tendency of the particles to coalesce (which will increase, by their mutual induction, as two neighbours approach each other) will be greatest near the ground. Thus it may be (each particle gathering to itself its neighbours successively till their united density exceeds that of the atmosphere generally) that some rain-drops are formed, and that in greatest abundance, near the ground. If this be the true cause of any substantial part of the phenomenon in question, then as the variation of intensity of electrical polarization of the particles will vary with height most rapidly near the ground, so the variation in the rainfall near the ground should be more rapid than at a greater elevation; and such is, indeed, the fact. Also, if the idea be correct, it will probably serve to explain other phenomena which it was not specially conceived to meet; and so it does. For, first, it requires that the rainfall over even ground, where the electrical tension is relatively weak, should be less than over similarly

situated forest-land, where, at the tops of the trees, ends of branches, and edges of leaves, the tension is high; and this is in accordance with observation. And secondly, the tension being relatively high at the tops of the elevations of a mountainous district, the rainfall should be greater there than in the neighbouring plains; this, again, is borne out by observation. Further, at the commencement of a passing thunder-storm, a sudden heavy shower of rain will often fall for a few moments, and then suddenly cease. May not this arise from the approach, by the agency of opposite wind-currents, of detached masses of oppositely charged clouds, the process, just described, of formation of rain-drops going on rapidly in each mass as the two come near each other, and stopping when, by a flash of lightning between them, the two masses are brought into the same electrical condition?

An experimental test of this idea would be to repeat Dalton's measures of the pressure of vapour in the vacuum space of a mercurial barometer-tube (filling that space with air and a little water), and compare the values found when the mercury was charged with electricity and when not so charged. If in the former case a less pressure was found, we might conclude that the particles of vapour are really susceptible of electric induction, and the amount of difference existing would enable us to estimate whether the attractions of the particles upon each other were strong enough to cause the formation of rain-drops hypothetically attributed to them above.

On a Scale for computing Humidity. *By* Professor J. D. Everett, *D.C.L.*

The scale in question is the invention of Mr. H. C. Russell, of Sydney Observatory. It consists of a sheet of paper ruled with vertical lines, each corresponding to a degree of the dry-bulb. These are traversed by a set of curved lines, each corresponding to a degree of humidity. A detached strip of paper divided into parts which correspond to every even tenth of a degree of difference between dry- and wet-bulb is applied (with its zero on the saturation-line) to the line representing the given dry-bulb temperature, and the curved line which cuts it at the division corresponding to the given difference indicates the resulting humidity.

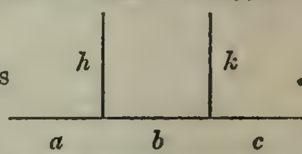
The scale is based on Glaisher's Tables; and any other table of double entry might be represented by a scale constructed on the same plan. Interpolation is much easier with such a scale than with a table.

Barometric Predictions of Weather. *By* Francis Galton, *F.R.S.*

It is notorious that the movements of the barometric column corrrespond in some sense to the changes of the weather, and especially to those of the wind's velocity; but they certainly take no notice of the rapid and tumultuous changes of its velocity which are recorded by the jagged lines of a pressure-anemometer. They therefore correspond to mean values of the weather; but the way in which, and the period of time for which those means should be taken, has yet to be determined. Comparison was made between a curve formed on the principle that the ordinate of each point represented the mean velocity of the wind for half an hour previous to, and half an hour subsequent to the moment indicated by the abscissa of that point, and it was drawn on the same time-scale as the corresponding barogram; the velocity-scale was so adjusted as to allow about the same range in the diagram for the two curves, and the ordinates were measured from above downwards (were, in fact, negative ordinates), in order that the increase of wind should be indicated by a descending curve, to correspond with the descending barogram, and *vice versâ.* The curve so made was called a curve of 1-hour period av. wind vel., and similar curves were drawn for 3-hour, 6-hour, 12-hour, 16-hour periods, and some others. It was manifest, on comparing these with the barogram, that a period of 1 hour was far too short, for its curve showed many large irregularities, of which the barogram took no cognisance; a period of 3 hours was much better; of 6 hours better still; and the maximum of correspondence began at 12 hours, and ended at 16, beyond which time the wind-velocity curve was less irregular than the baro-

gram. The correspondence was equally good at all periods, for which trial was made, between 12 and 16 hours, some parts agreeing better at the shorter, and others at the longer period. The former period is selected for discussion in this memoir. The data are derived from those of the continuous weather-records lately published by the Meteorological Committee for the first quarter of 1869, so far as they refer to Falmouth. The correspondence of the 12-hour period av. wind vel. curves for Falmouth, with the barogram, is fairly satisfactory. The flexures of the two curves are, on the whole, simultaneous, since neither curve habitually anticipates the other; but they are seldom absolutely simultaneous. They correspond in extreme positions as closely as in near ones, proving that it is not the absolute height of the barometer, but the variations in its height, which indicate changes of weather. The dominant influence of the wind-velocity upon the barometer was made manifest by underlining with different colours the epochs of polar and equatorial winds, and showing that the correspondence of the two curves was, on the whole, much the same, whatever might be the quality of the wind.

The reason of this correspondence of the barogram with a 12-hour av. vel. curve was then discussed, and was described as similar to that which causes a suitably constructed barometer, when plunged into troubled water, to sympathize, not solely with the height of wave exactly above its cistern, but also with that of every point in a surface area whose diameter is a function of the depth of immersion. So the barometer sympathizes with the condition of the air for some distance on all sides of it; and as there is a general easterly movement of the air over England, it appears that the diameter of the circle of air which affects the barometer is such as to require, on the average, 12 hours to pass over an observatory. A barometer would therefore be affected by an atmospheric wave of exceptional magnitude before it reached the observatory. According to this argument, the effects of the independent variables, temperature, and damp must be treated on the same system of 12-hour period of average as the wind's velocity. Consequently the following formula is easily deduced. Let h, k be two successive barometric heights, at an interval of 6 hours, a the 6-hour interval that precedes h, b the 6-hour interval between h and k, and c the 6-hour interval which succeeds k. Call v_a, t_a, d_a the 6-hourly average during the period a of wind-velocity, temperature, and vapour-tension, and use a similar notation for b and c. The units adopted were hundredths of an inch for barometer and vapour-tension miles per hour for wind-velocity, and degrees Fahr. for temperature. The general formula was



$$h-k=m(v_{a+b}-v_{b+c})+n(t_{a+b}-t_{b+c})+r(d_{a+b}-d_{b+c}).$$

The coefficient m was found $=-2$ by taking a number of selected equations in which neither t nor d had materially varied during the period discussed; n was found $=-1$ by taking the extreme range of the barometer under the influence of changed temperature alone, the other variables being constant; and d was assumed $=-1$ also, that is, it was taken at its real value, but with a negative ordinate; all the ordinates are negative, because v, t, and d all decrease as h increases. Now

$$v_{a+b}-v_{b+c}=\tfrac{1}{2}\{(v_a+v_b)-(v_b+v_c)\}=\tfrac{1}{2}(v_a-v_c),$$

and similarly for t and d, whence

$$h-k=(v_c-v_a)+\tfrac{1}{2}(t_c-t_a)+\tfrac{1}{2}(d_c-d_a), \text{ or}$$

$$v_c=(h-k)+v_a+\tfrac{1}{2}(t_a-t_c)+\tfrac{1}{2}(d_a-d_c).$$

It will be observed that v_b is necessarily eliminated. Comparison was made between the value of v_c as predicted by this equation with its value as ascertained by fact. About 100 cases of marked changes of weather were taken, and it appeared that the average error was one-third greater than if v_c had been predicted as simply equal to v_b. The reason why the average error is so large, notwithstanding the

general truth of the principle of prediction is, first, that correctness in the result depends on the correctness of all the elements of the formula, but their values are only mean values and cannot be relied on in individual cases; secondly, any error in the theoretical expectation of the value of v_{b+c} is, on the whole, doubled in the prediction of v_c, because the difference between what was expected of v_{b+c}, and what was fulfilled in v_b, is heaped on to v_c, which has, therefore, to bear the entire error of expectation of v_{b+c}. It was concluded from this, and from other previous deductions from some years of Dublin observations, to which reference was made, that the fame of the barometer is due to its success in predicting a type of storm very rarely met with in the British Isles, but frequently in hurricane-latitudes, when the fall of the mercury far outstrips the increasing severity of the weather. In ordinary gales, and much more in ordinary weather, the author considered the barometer to be useless as a guide when consulted without a knowledge of what is occurring at adjacent stations—in short, without such information as is supplied by the 'Daily Weather Report.'

On the Temperature of the Air at 4 feet, 22 feet, and 50 feet above the Ground. By JAMES GLAISHER, *F.R.S., F.R.A.S.*

In the report to the British Association, for 1866, on the experiments made by means of balloon, I stated that the law of decrease of temperature with increase of elevation was variable throughout the day, and variable in different seasons of the year, that at about sunset the temperature was nearly the same up to 2000 feet, and that at night (from the only two night-ascents) the temperature of the air increased from the earth upwards. From this it was evident that, instead of only a few ascents being necessary, a much larger number were required than it was possible for me to make. Fortunately, in the second year of the balloon experiments, I planted at the Royal Observatory, Greenwich, a dry- and a wet-bulb thermometer at the height of 22 feet above the soil, readings of which have been taken daily since that time, at the hours of 9 A.M., Noon, 3 P.M. and 9 P.M. Sometimes readings at the higher point were above those at 4 feet from the ground; but no particular value was attached to this fact, until, on the observations made in M. Giffard's captive balloon being reduced, the results proved that the decrease of temperature with increase of elevation had a diurnal range, and was different at different hours of the day, the changes being greatest at about midday, and least at or about sunset (see Report for 1869), whilst sensible changes occurred within 30 feet of the earth. In consequence, the observations made at the height of 22 feet were reduced by taking the differences between the readings of the two thermometers, and affixing the sign *plus* (+) to that difference when the temperature was higher at the higher elevation, and the sign *minus* (−) when *vice versâ*. All the observations made in the years 1867–70 were treated in this way.

By selecting the greatest number with a + sign, and the greatest with a − sign in each month, it was found that in the *winter* months the temperature at 22 feet height ranged from 2 to 4 degrees above, and from 1 to 2 degrees below, that at 4 feet, and in the *summer* months from 4 to 5 degrees above to 5 or 6 degrees below that at 4 feet height, as will be seen by the following Table:—

		(+).	(−).
1867–70,	January	4·3	1·9
	February	2·5	1·5
	March	1·9	4·9
	April	4·2	5·5
	May	4·7	6·1
	June	4·1	6·6
	July	4·3	5·5
	August	5·2	6·1
1867–69,	September	4·0	4·8
	October	3·5	3·3
	November	4·8	2·6
	December	2·3	1·2

The ratio of minus readings to plus readings was, in January and February, 1 to 5 at all hours during the day hours; in March, April, August, and September during the day, one of equality. In May, June, and July the ratio was 3 to 2, in October 1 to 4, in November 1 to 7, and in December 1 to 10. At the hour of 9 P.M., throughout the year, it was 1 to 7; the monthly means of these differences in each year are shown in the following Table:—

Monthly means of excess and defect of Temperature at 22 feet, above and below that at 4 feet.

Date.	Differences.				Date.	Differences.			
	9 A.M.	Noon.	3 P.M.	9 P.M.		9 A.M.	Noon.	3 P.M.	9 P.M.
Jan. 1867...	+0·48	+0·24	+0·31	+0·70	July 1867...	−0·48	−0·34	+0·40	+0·60
1868...	0·24	0·11	0·23	0·38	1868...	1·76	1·72	−1·77	0·55
1869...	0·43	0·28	0·50	0·60	1869...	0·36	0·81	1·10	.0·78
1870...	+0·66	+0·23	+0·55	+0·54	1870...	−0·74	−0·41	−0·65	+1·04
Febr. 1867...	+0·16	−0·04	+0·37	+0·46	Aug. 1867...	−0·78	+0·29	+0·63	+0·78
1868...	0·33	+0·07	0·41	0·45	1868...	0·97	−0·97	−0·38	0·50
1869...	0·10	0·05	0·34	0·61	1869...	1·14	0·31	+0·20	0·83
1870...	+0·12	+0·05	+0·39	+0·45	1870...	−1·07	−0·96	−0·78	+1·30
Mar. 1867...	−0·26	−0·65	−0·07	+0·31	Sept. 1867...	−0·65	−0·12	+0·21	+0·63
1868...	0·31	+0·32	+0·20	0·39	1868...	1·70	1·10	−0·24	0·68
1869...	0·39	−0·27	0·00	0·50	1869...	−0·65	−0·46	0·00	+0·80
1870...	−0·22	−0·26	−0·01	+0·54	1870...	...	...	...	...
April 1867...	−0·59	−0·18	−0·17	+0·34	Oct. 1867...	−0·45	−0·24	+0·51	+0·70
1868...	0·27	0·93	+0·25	0·53	1868...	−0·28	−0·27	0·48	1·12
1869...	1·05	0·30	0·08	0·36	1869...	+0·10	+0·18	+0·89	+1·06
1870...	−0·54	−0·37	+0·44	+0·88	1870...	...	...	...	...
May 1867...	−0·93	+0·10	−0·08	+0·47	Nov. 1867...	+0·14	−0·10	+0·75	+0·91
1868...	0·37	−0·19	0·21	0·30	1868...	0·22	+0·04	0·44	0·42
1869...	0·43	0·52	0·60	0·37	1869...	+0·36	+0·26	+0·53	+0·93
1870...	− ·79	−1·13	−0·87	+0·81	1870...	...	...	...	...
June 1867...	−0·44	−0·51	+0·22	+0·76	Dec. 1867...	+0·50	+0·31	+0·50	+0·24
1868...	0·99	1·23	−0·61	0·72	1868...	0·38	0·42	0·41	0·52
1869...	0·95	0·56	0·82	1·07	1869...	+0·49	+0·22	+0·31	+0·39
1870...	−0·68	−1·17	−1·02	+0·80	1870...	...	...	...	...

From the above Table it will be seen that the *mean* temperature of the air at 22 feet height was higher than at 4 feet, at all hours of the day and night, during the months of January, February, November, and December; in the early afternoon, and during the night, in the months of March, April, August, September, and October; and in the evening hours, and during the night, in May, June, and July.

The mean monthly temperatures of the air at 22 feet height, for all the years, were then taken, and found to differ from those at 4 feet, as follows:—

	At 9^h A.M.	At Noon.	At 3^h P.M.	At 9^h P.M.
	°	°	°	°
1867–70, January	+0·5	+0·2	+0·4	+0·6
February	+0·2	0·0	+0·4	0·5
March	−0·3	−0·2	0·0	0·4
April	0·6	0·5	+0·2	0·5
May	0·6	0·4	−0·4	0·5
June	0·8	0·9	0·6	0·8
July	0·8	0·8	0·8	0·7
August	1·0	0·5	−0·1	0·9
1867–69, September	1·0	0·6	0·0	0·7
October	−0·2	−0·1	+0·6	1·0
November	+0·2	+0·1	0·6	0·8
December	+0·5	+0·3	+0·4	+0·4

Thus the *plus* sign preponderates, indicating greater warmth above, during the day and night, in January, February, October, November, and December, and during the night throughout the year.

A second thermometer, properly protected from radiation, was placed in the middle of the year 1869 at the height of 50 feet; and since then its readings have been regularly taken. The mean monthly temperatures of the air, at 50 feet height, were found to differ from those at 4 feet, as follows:—

	At 9^h A.M.	At Noon.	At 3^h P.M.	At 9^h P.M.
1869, October	$+0\overset{\circ}{\cdot}2$	$-0\overset{\circ}{\cdot}5$	$+0\overset{\circ}{\cdot}7$	$+1\overset{\circ}{\cdot}5$
November	0·6	+0·5	0·8	1·4
December	0·9	0·3	0·5	0·5
1870, January	1·1	+0·3	0·7	0·9
February	+0·1	−0·3	+0·3	0·5
March	−0·3	1·2	−0·7	0·7
April	0·9	2·2	1·7	1·4
May	2·4	3·6	2·8	1·1
June	2·4	3·8	3·1	1·1
July	1·8	2·9	2·8	1·2
August	−1·7	−2·7	−2·0	+1·7

Thus we have the unexpected result that the mean monthly temperature of the air at 22 feet and at 50 feet height is higher during the evening and night-hours throughout the year than at the height of 4 feet, and also higher, night and day, during the winter months. By selecting those days with a sky covered by dense clouds, it was found that there was on such days no difference between the temperature at 4 feet, 22 feet, and 50 feet height. At the height of 50 feet, in the summer months, the temperature during the day was frequently 6 and 7 degrees lower than that at 4 feet, and at night 5 or 6 degrees higher.

On a New Electro-Magnetic Anemometer, and the mode of using it in Registering the Velocity and Pressure of the Wind. By JOHN J. HALL.

After describing at some length the difficulties attending the use of the present forms of anemometrical apparatus, arising from the fact that few houses are built with any means of access to the roof, also from the interference of trees and undulatory surfaces of land, &c., and having showed the practical results that would be derived from the use of electricity, the author proceeded to describe the apparatus devised (and exhibited) by him. One of the main objects for which it is intended is the determination of interval or hourly velocities. The following is a brief *résumé* of its principles and construction:—

The anemometer consists of two parts, viz. Velocity apparatus and Registering apparatus.

The first consists of a set of Robinson's hemispherical cups, which communicate their motion downwards into a brass box, where it is reduced in angular velocity and causes a contact-disk or commutator (in which two platinum contact-pins are fixed equidistant from one another) to revolve in tenths of a mile. An insulated metallic lever, having a platinum working face, stands on each side of the disk so that, upon the completion of every $\frac{1}{500}$ mile, one or other of the contact-pins comes into contact with the two levers, thus uniting them and completing the circuit. The levers, which are jointed at their opposite ends, are raised a few degrees (of circles, whose radii they represent), and then fall back to their normal position, ready to be taken up by the next pin, and so on.

The Recording apparatus consists of a train of wheels and pinions working in a frame or between two brass plates, the arbors of which project through a dial-plate (whereon the circles and figures are engraved), and carry the hands. These wheels are driven by a weight attached to a line which is wound round a barrel; and a locking pin-disk (the pinion of which works in the first wheel) is released at every contact of the cup apparatus by an electro-magnet, which unlocks the pin-disk and allows the first hand to advance $\frac{1}{500}$ mile on the graduated dial by a jump similar to the minute-hand in remontoire clocks.

By turning "on" a "strike-silent" stop, a hammer lever is brought into connexion with the escapement, and strikes a ball at every contact; the observer has therefore nothing to do in noting interval or hourly velocities but to notice the seconds' hand of his watch or chronometer (a split-seconds or chronograph would be preferred), while he counts the number of times the bell is struck, each of which corresponds to the $\frac{1}{300}$ mile, and, by formulæ arranged and explained by Mr. Hall (who has also arranged a comprehensive series of tables for use with the instrument) the hourly velocity may be readily deduced.

The following formula has been arranged for deducing the hourly velocity of the wind from observations during intervals of minutes and seconds.

Let T be the interval of observation in minutes and seconds, expressed decimally, 60 constant (min.=1 hour), and x the quantity required, which will represent the number of times T is contained in one hour, ·05 unit of distance, b number of beats on bell, x as before, and V velocity required; then

$$x = \frac{60}{\mathrm{T}} =$$

$$\therefore \cdot 05 \times b \times x = \mathrm{V}.$$

Supposing, therefore, the bell is struck 15 times in 1 min. 30 sec., expressed decimally 1·50 min.; then

$$x=\frac{60}{1{\cdot}50}=40; \qquad \therefore \cdot 05 \times 15 \times 40 = 30{\cdot}00 \text{ miles.}$$

By noticing the exact seconds upon which the first and last beat are struck, the results will be *as accurate as if the instrument were capable of recording the one-thousandth part of a mile*, while the battery is less called into action.

In noting velocities extending over long periods of time, the instrument is read in the same manner as the ordinary cup-and-dial anemometer.

This paper, which was of considerable length, was illustrated by the Electrical Anemometer (by Messrs Negretti and Zambra, under Mr. Hall's directions) and mechanical diagrams.

On the Rainfall of the United States. By Professor J. Henry.

Heat, Light.

Queries respecting Æther. By Charles Brooke, *M.A., F.R.S.*

When light and caloric were supposed to consist of material molecules, the hypothesis of the universal existence of a transmitting medium was unnecessary, since particles of matter might with the utmost freedom be projected through vacuous space; but as light and heat are now generally admitted to consist not of transmitted matter, but of transmitted vibratory motion (and why may not electricity, so freely interchangeable with the former, be admitted into the same category?), the necessity of the existence of a highly elastic and attenuated transmitting medium, pervading infinite space, becomes at once apparent; and this medium, hitherto not cognizable to our senses, has been termed "æther." But it has been further assumed that *æther* is *alone* capable of transmitting the extremely rapid vibrations of light and heat, and that it must therefore necessarily pervade or permeate all kinds of sensible matter. The questions proposed to be raised in this communication are the necessity of this *interstitial* hypothesis, and the probable capability of ordinary matter to transmit the vibrations of light and heat.

It is now generally admitted that when a body becomes heated, its own particles, and not merely those of the supposed interstitial æther, are thrown into a state of vibratory motion, the amount of heat corresponding probably to the amplitude of the vibrations; hence a certain amount of energy has been communicated to those particles, and (at all events, in the case of celestial radiations) the molecules of æther must previously have possessed the energy or *vis viva* which they have com-

municated. Hence æther, being susceptible of *vis viva*, has recently been admitted to be *ponderable*; but this admission is not a necessary consequence; for although the idea of existing energy is associated with that of *weight*, in consequence of the constant energy acquired by gravitation having been taken as the measure or unit of energy however acquired, there is no necessary connexion between them. Suppose, for example, that a flea were placed on an orbitating planet of the size of a pumpkin; while its muscular energy would remain undiminished, its weight would be infinitesimal, and the first leap would obviously plunge it into infinite space, to perform subsequently perhaps an independent orbit.

The only basis on which the *interstitial-æther* hypothesis rests is the assumed incapacity of ordinary matter, whether in the solid, liquid, or gaseous state, to transmit the vibrations of light and heat, because the only vibrations hitherto recognized, namely those of sound, are almost immeasurably slower than those of light and heat; the one being numbered by at most a few thousands, the other by hundreds of millions of millions in one second of time. But it must be borne in mind that sonorous vibrations are always longitudinal, in the production of which *repulsive* forces are *alone* concerned; whilst, on the contrary, light- and heat-vibrations are necessarily transverse, and the production of these is solely due to *attractive* forces. Now these respective forces obey very different laws; for whilst attractive forces obey generally, and probably universally, the law of the inverse square of the distance, molecular repulsion must obviously, at all events in gaseous matter, obey the law of the inverse cube of the distance; therefore from the rate of transmission of longitudinal vibrations nothing can be predicated respecting the rate of transmission of transverse waves. It has been asserted that molecular repulsion is a dynamical resultant effect, and therefore incapable of expression by a statical law; but it is very doubtful whether molecular attraction is not equally a dynamical sequence, and therefore not a whit more entitled to claim a statical law than the former.

It has been shown from the investigations of Mr. Norman Lockyer that incandescent gases existing in the vicinity of the sun are capable of *initiating* vibrations of definite periods, which are moreover occasionally accelerated or retarded by the proper motion of the emitting gas, just as sound-waves have been shown by Savart to be accelerated or retarded, and the sound consequently raised or lowered in pitch, by the proper motion of the body producing the vibrations. What reason can there then be for doubting that gaseous matter is capable of transmitting heat-waves, and, if so, of likewise transmitting the waves of light, since the two are so intimately connected by the identical phenomena of reflexion, refraction, and polarization? may not, in fact, in some instances the perceptions of light and heat be but different sensuous impressions produced by the same vibrations?

Now in the denser forms of matter, namely the solid and liquid, it appears that the wave-lengths of excited transverse vibrations are indefinitely modified, probably by the more energetic action of repulsive forces; for whilst any given kind of matter in the solid or fluid state is found, when incandescent, to emit light- and heat-waves of all lengths, and so to form a continuous spectrum, the same matter in the form of incandescent gas will emit only a few sets of waves of definite and invariable lengths, forming an interrupted spectrum of bright lines; and moreover some of these wave-lengths are frequently found to bear very simple numerical ratios to each other. And even in gaseous matter it has been observed that the bright lines in the spectrum become narrower and more sharply defined by rarefaction, and, on the contrary, broader and less defined by condensation. Moreover, as regards the density of the absorbing medium, the absorption-bands in the spectrum appear to obey the same law as the bright lines. In other words, every kind of matter appears to be capable of emitting or absorbing its own peculiar waves, according to its tenuity, that is, as the results of molecular attraction are less and less interfered with by those of repulsion. The well-known peculiar incapacity of any given transcalent substance to transmit the heat-rays emitted by a heated portion of the same substance, or, in other words, the ability of the molecules to freely appropriate the wave-motion that has been induced in *some* intervening medium by similar molecules, seems further to argue that ordinary matter is capable of assuming vibrations having the extreme rapidity of those of light and heat; and that

there exists no valid ground for a distinction between light and heat in this respect is further confirmed by the experiments of Mr. B. Stewart, who has shown that the emission of light by incandescent bodies closely corresponds with their absorptive power (whether selective or otherwise) when not incandescent, and, further, that even in the decomposition of light into two polarized beams by the tourmaline, that substance emits when incandescent the ray that is otherwise absorbed. Can there, then, be any valid reason for doubting the ability of ordinary matter to transmit those transverse vibrations which it is obviously capable of either absorbing or emitting? and if so, what ground is there for the hypothesis that the transmission of light- and heat-waves necessitates the presence of imperceptible æther in the interstices of perceptible matter?

If the existence of æther in infinite space, essential to the undulatory theory, be admitted, it may be asked how is it possible to conceive its exclusion from *any* portion of space? A very simple hypothesis, propounded by the writer in the Introduction to the last edition of his 'Elements of Physics,' will meet this difficulty—namely, that æther (like its fluid namesake with water) is *immiscible* with known gaseous matter. This, it must be admitted, is sheer hypothesis; but if true, it must ever remain so, æther being in that case beyond the reach of human ken: of this we may, however, rest assured, that if it be not *wanted* in and around even our corporeal frames, *it is not there*; the contrary supposition would be inconsistent with the infinite wisdom of the Creator of the universe.

On certain Objections to the Dynamic Theory of Heat. *By* H. WHITESIDE COOK.

In this paper the author first endeavoured to show that heat must necessarily be a *force* of a permanent nature, could not possibly be a mere affection of matter, and, as is asserted by the believers in the "Dynamic" hypothesis, that it must be in the nature of an "energy," and not an "impulse."

He then proceeded to analyze the nature of heat as described in the thermodynamic theory, and brought forward arguments to show that the causes which produce heat would not produce the molecular motion presumed, and that, on the other hand, allowing this molecular motion to exist, it would not produce the effects which are produced by heat. He proceeded, in conclusion, to consider one or two of the experiments on which the dynamic hypothesis was based, and showed that they were in no way incompatible with the old theory of a caloric or substantive heat. In short, the argument of the paper was:—that though such forces as electricity, magnetism, &c. were probably justly considered to be only affections of matter, it was a mistake to conclude the same thing of heat; that if the attractivity of matter be a permanent energetic force, then heat, the force which counteracts that attractivity among molecules, must also be a permanent energetic force; for a force of impulse cannot cope with a perpetual energetic force; however great the impulse, it must soon be beaten; and were heat a condition and not an entity, then it would be but a passing phenomenon.

In dealing with the experiments which are supposed to substantiate the dynamic hypothesis, the author dwelt especially on Davy's celebrated experiment of liquefying ice by friction, when he showed that the increment of heat added to the ice was very small in comparison with the amount of heat contained by the ice when at the temperature of 32° Fahr., and that the molecular agitation to which it was subjected would cause it to absorb this heat from the atmosphere of caloric, which, on the substantive theory, would *ex hypothesi* surround it. He next spoke of the fall of temperature which takes place when compressed air is allowed to escape from the confining vessel (an experiment which is put forward by the exponents of the dynamic theory as instancing the conversion of heat into mechanical energy), and pointed out that in the preparation of the experiment the compression of the air had forced out of it some of the heat that it contained. When, then, it was allowed to escape, the air brought out less heat than it took in, the difference being the amount which had been given out in cooling after the original compression. The author added that these experiments could not be said to substantiate the dynamic theory—and that if he did not mention more of them, it was because those present

would be able to call them to mind themselves and apply to them reasoning precisely similar.

The author attached great importance to the question, because he thought that in erroneously considering heat to be molecular vibration, we lost sight of the true explanation of electricity, which he believed to be neither more nor less than that very vibration or molecular motion which the dynamic theory called heat.

On the Wave Theory of Light, Heat, &c. By Dr. Henry Hudson.

Huyghens (to explain double refraction) assumed a *second* vibrating medium as consisting of "the molecules and æther conjointly;" and Fresnel's grand theory rests on the same foundation. As molecular vibrations in air (sound-waves) are 10,000 times *longer* and 869,000 times *slower* than etherial waves, the author rejects this combination as inadequate to account for the very minute difference in the retardation of the doubly refracted rays in crystals. He then adduces several cases, especially in polarized light, *unexplained* on Fresnel's theory, and proceeds to show that all the difficulties in Fresnel's theory can be removed by considering the "æther" to consist of *two media*, each possessed of equal and enormous self-repulsion, and both existing in equal quantities throughout space, being also *mutually indifferent* (neither attracting nor repelling), and that their vibrations consequently always take place *in perpendicular planes.* He then suggests as an experimental test of this view, "that the ordinary refracted ray, through Iceland spar, cannot be made to show any phenomena of *Interference* with the APPARENTLY similarly polarized ray obtained by total reflexion from glass," because, on this view, their vibrations are in different media. After discussing many curious and interesting questions, he pointed out that the *two Electricities* fulfil the requirements of the theory, being, as he asserts, *mutually indifferent,* and constitute *the æther.* Electrical phenomena the author would explain by the existence of "waves of translation" as well as "waves of vibration" affecting the molecules of bodies—the former being most prominent in "statical phenomena" (induction especially), and the latter more generally observed in what is denominated "the electric current."

Optics.

On the Immersion Method of Illumination of the Microscope. By Dr. John Barker.

After showing the defects of the present methods as exhibiting merely shadows and caustics of reflection and refraction, and markings resulting very often from the relative opacity and transparency of the parts of an object, the author was led to believe, from the study of the way in which objects are best illuminated for unassisted vision, that this was the method to which we should endeavour to approximate in the illumination of microscopic objects. The adaptation of the immersion plan in condensers of various forms seemed to him to best fulfil these requirements. The object would be illuminated by very oblique light, the oblique rays being most economized, undergoing less loss and less dispersion. The author brought forward several forms of this mode of illumination, in which a flat-topped paraboloid was used, which, he stated, gave very good results with a two-thirds used with binocular microscopes; another was a flat-topped paraboloid to be used above the object, and in the centre of which (the glass paraboloid) the power was placed so as to light up the object under the highest powers with reflected light. The ordinary achromatic condenser, too, he thought, might be greatly increased in value by adapting it to the immersion plan.

On the New Binocular Microscope. By S. Holmes.

The author showed that the views of objects seen through a microscope, being

pseudoscopic and superficial, gave no trustworthy information of structure—and hence the disagreements of observers.

Describing the binocular microscopes preceding his own, he contended that they failed to give true appearances, because the second image was but a distorted reflex of the first, and could not thus give true stereoscopic relief.

Such relief being due to the direct convergence of the axes of two eyes to one object, he had after some years succeeded in making a binocular microscope capable of showing perspective distance, by employing two equally inclined microscopes of equal power.

Eight drawings of mechanical arrangements accompanied the paper; and the instruments on this plan were shown to secure to the microscopist and amateur the following advantages:—

1. The ease of observation by the *equal* use of both eyes, and a natural erect view for dissecting-purposes.

2. Perfectly stereoscopic views of opaque objects, and distinct definition of thick transparent ones.

3. Pseudoscopic vision for the illustration and verification of all objects, and convertibility into a monocular microscope by the turn of a milled head.

On Colour-vision at different points of the Retina. *By* J. Clerk Maxwell, *LL.D., F.R.SS. L. & E.*

It has long been known that near that point of the retina where it is intersected by the axis of the eye there is a yellowish spot, the existence of which can be shown not only by the ophthalmoscope, but by its effect on vision. At the Cheltenham Meeting in 1856 the author pointed out a method of seeing this spot by looking at that part of a very narrow spectrum which lies near the line F. Since that time the spot has been described by Helmholtz and others; and the author has made a number of experiments, not yet published, in order to determine its effects on colour-vision.

One of the simplest methods of seeing the spot was suggested to the author by Prof. Stokes. It consists in looking at a white surface, such as that of a white cloud, through a solution of chloride of chromium made so weak that it appears of a bluish-green colour. If the observer directs his attention to what he sees before him before his eyes have got accustomed to the new tone of colour, he sees a pinkish spot like a wafer on a bluish-green ground; and this spot is always at the place he is looking at. The solution transmits the red end of the spectrum, and also a portion of bluish-green light near the line F. The latter portion is partially absorbed by the spot, so that the red light has the preponderance.

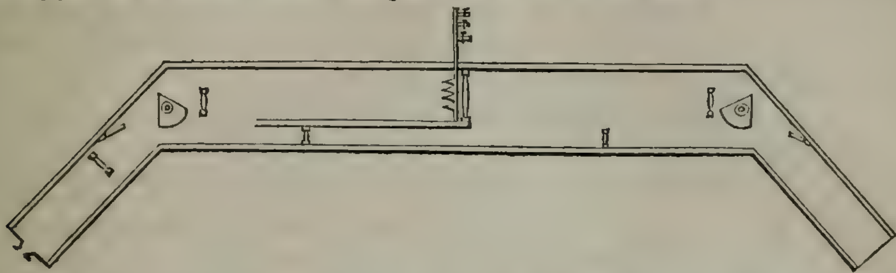
Experiments of a more accurate kind were made with an instrument the original conception of which is due to Sir Isaac Newton, and is described in his 'Lectiones Opticæ,' though it does not appear to have been actually constructed till the author set it up in 1862, with a solid frame and careful adjustments. It consists of two parts, side by side. In the first part, white light is dispersed by a prism so as to form a spectrum. Certain portions of this spectrum are selected by being allowed to pass through slits in a screen. These selected portions are made to converge on a second prism, which unites them into a single beam of light, in which state they enter the eye. The second part of the instrument consists of an arrangement by which a beam of light from the very same source is weakened by two reflections from glass surfaces, and enters the eye alongside of the beam of compound colours.

The instrument is formed of three rectangular wooden tubes, the whole length being about nine feet. It contains two prisms, two mirrors, and six lenses, which are so adjusted that, in spite of the very different treatment to which the two portions of a beam of light are subjected, they shall enter the eye so as to form exactly equal and coincident images of the source of light. In fact, by looking through the instrument a man's face may be distinctly seen by means of the red, the green, or the blue light which it emits, or by any combination of these at pleasure.

The arrangement of the three slits is made by means of six brass slides, which can be worked with screws outside the instrument; and the breadth of the slits can be read off with a gauge very accurately.

In each observation three colours of the spectrum are mixed and so adjusted that their mixture is so exactly equivalent to the white light beside it, that the line which divides the two can no longer be seen.

It is found that in certain cases, when this adjustment is made so as to satisfy one person, a second will find the mixed colour of a green hue, while to a third it will appear of a reddish colour, compared with the white beam.



But, besides this, it is found that the mixed colour may be so adjusted that, if we look directly at it, it appears red, while if we direct the eye away from it, and cast a sidelong glance at it, we see it green. The cause of this is the yellow spot, which acts somewhat as a piece of yellow glass would do, absorbing certain kinds of light more than others; and the difference between different persons arises from different intensities of the absorbing spot. It is found in persons of every nation, but generally stronger in those of dark complexion. The degree of intensity does not seem to depend so much on the colour of the hair or the iris of the individual, as to run through families independent of outward complexion.

The same difference is found between different colour-blind persons; so that in the comparison of their vision with that of the normal eye, persons should be selected for comparison who have the yellow spot of nearly the same intensity.

In my own eye the part of the spectrum from A to E is seen decidedly better by the central part of the retina than by the surrounding parts. Near F this is reversed, and the central part gives a sensation of about half the intensity of the rest. Beyond G the central part is again the most sensitive, and it is decidedly so near H.

Before I conclude I wish to direct the attention of those who wish to study colour to the exceedingly simple and beautiful series of experiments described by Mr. W. Benson in his works on colour. By looking through a prism at the black and white diagrams in his book, any one can see more of the true relations of colour than can be got from the most elaborately coloured theoretical arrangements of tints.

On the Cause of the Interrupted Spectra of Gases.
By G. Johnstone Stoney, *M.A., F.R.S.*

In 1867 Mr. Stoney had instituted a comparison between the internal motions of gases and the phenomena of light*, from which it appeared that the lines in the spectra of gases must be attributed to periodic motions *within* the molecules, and not to the little irregular journeys which the molecules make amongst one another.

In the present communication he endeavoured to advance another step. Each such periodic motion in the gas will throw off waves in the æther. These waves will in general not be pendulous; in fact the circumstances would need to be altogether exceptional which would restrict them to so simple a form. But whatever the character of each wave, provided only that all the waves of the undulation are alike, it follows from Fourier's well-known theorem that the undulation may be adequately represented by the simultaneous advance of a number of superposed *pendulous* undulations—one consisting of waves of the

* See a paper in the Philosophical Magazine for August 1868, p. 132. Readers of that paper are requested to correct "16^2 or upwards of 250" (on p. 134), into "$\sqrt{16}$".

periodic time of the original disturbance, and the rest having periodic times which are submultiples of this. Thus, if T be the periodic time of the original motion in the gas, we are at liberty to regard the undulation, whilst traversing the open æther, as consisting of a multitude of coexisting pendulous undulations with periods T, $\frac{1}{2}$T, $\frac{1}{3}$T, &c. So long as the motion is propagated through undispersing æther, the waves of all lengths travel at the same speed. The component undulations therefore strictly accompany one another; and accordingly the resultant general undulation maintains whatever complicated form it may have had at first.

But if the light enter a dispersing medium, such as glass, an entirely new state of things arises. In glass, waves of different lengths travel at unequal velocities. Each pendulous undulation will accordingly proceed across the glass at a rate determined by its own special periodic time. In this way the component undulations part company, and if the glass be in the shape of a prism they will emerge in different directions; each giving rise to a distinct line in the spectrum of the gas. It thus appears that one of the periodic motions in the molecules of a gas will in general be the source of several lines in its spectrum, and that all the lines thus arising from one original motion will have periodic times which are terms of the harmonic series T, $\frac{1}{2}$T, $\frac{1}{3}$T, &c.; T being the periodic time of that motion in the gas to which they are all due.

Moreover it further appears from the structure of Fourier's theorem, that the form of the original disturbance will determine whether all the harmonics exist, or only some of them. Where only some at irregular intervals exist, we have lines of a spectrum of the Second Order; where all or a long series of consecutive harmonics exist, we have the beautiful spectacle of one of the fluted series in spectra of the First Order. The fluted appearance is due to the varying brightness of the successive lines, or, in other words, to the values of the coefficients of the successive terms of Fourier's series, which again depend on the character of the original disturbance. Drawings were exhibited of the patterns of the flutings which would result from various simple hypotheses as to the original disturbance; and some of these drawings bore a striking general resemblance to patterns which occur in nature.

Sufficiently detailed observations on spectra of the First Order have not yet been made fully to test this theory or afford materials for its application to the various inquiries of interest which it suggests; and Mr. Stoney was engaged in endeavouring to supply this want. Meanwhile it may be observed in general that the closeness of the ruling in spectra of the First Order indicates that the lines are very high harmonics of relatively slow original vibrations—vibrations which in many instances correspond to wave-lengths of more than a millimetre in length, and consequently have a periodic time of several twelfth-seconds (the XIIth-second meaning $\frac{1}{10^{12}}$ of a second of time).

In the case of nitrogen, two systems of lines giving fluted columns have been observed—one at the red end of the spectrum, formed by lines very closely packed together, the other at the blue end of the spectrum, consisting of lines more widely spaced. Plücker counted 34 dark lines (*i. e.* 35 bright lines) in one of the blue flutings, viz. that one which lies to the left of the letter C in his diagram (Phil. Trans. for 1865, plate 1). Judging from the diagram, this fluting would seem to extend about from wave-length 44·8 to 45·6 eighth-metres. If so, we may conclude that the 35 bright lines of graduated intensity of which it consists are from about the 1960th up to the 1995th harmonics of a wave-length of about 0·89376 of a millimetre. This wave-length corresponds to about 3 XIIth-seconds of time, which may accordingly be regarded as a rough approximation to the periodic time of the motion in the molecules of nitrogen by which the blue flutings are occasioned.

When lines of spectra of the *Second* Order are the result of motions in a gas so slow as this, it would not be practicable to determine the periodic times of the original motions from observations upon spectra of this kind; for in this case the harmonics, if the positions of all of them were laid down on a map of the spectrum, would be so crowded together that it would be difficult to determine with certainty to which of them a line of a spectrum of the Second Order should be referred. Per-

haps we may obtain assistance in such cases from disposing the apparatus so as to present to the eye spectra of the First Order and of the Second Order in rapid succession (see Plücker, Phil. Trans. for 1865, p. 10. § 24).

But there seems to be at least one case of a more rapid periodic time, viz. that of certain lines of hydrogen. The ordinary spectrum of the Second Order of this gas consists of the four well-known lines C, F, one near G, and *h*. Three of these lines, viz. C, F, and *h*, are to be referred to a single motion in the molecules of the gas. In fact they are the 20th, 27th, and 32nd harmonics of a wave-length (*in vacuo*) of 1·31217714 fifth-metre (the Vth-metre being $\frac{1}{10^5}$ of a metre, which is a little more than the diameter of a disk of human blood). This, taking the velocity of light to be 298 millions of metres, gives 4·4 XIVth-seconds as the periodic time of that motion in the molecules of hydrogen in which these three lines have their origin.

This determination may be accepted as very close to the truth. The most uncertain part of it is the velocity which has been assigned to light. The rest of the computation depends on Ångström's marvellously accurate measures of the wave-lengths in air of standard pressure and 14° C. temperature, reduced to wave-lengths *in vacuo* by Ketteler's observations on the dispersion of air; and the following Table will show how very close the calculated values are to those which were observed.

Observed wave-lengths, reduced to wave-lenghths *in vacuo*.	Calculated values.			Differences.
Xth-metres.	Xth-metres.		Xth-metres.	Xth-metres.
h=4102·37	$\frac{1}{32}\times$131277·14	=	4102·41	−0·04
F=4862·11	$\frac{1}{27}\times$131277·14	=	4862·12	−0·01
C=6563·93	$\frac{1}{20}\times$131277·14	=	6563·86	+0·07

The difference in no case amounts to an eleventh-metre, which is the limit within which Ångström thinks that his measures may be depended on.

Possibly some of the other harmonics, such as the 19th, 21st, 22nd, &c., which are not visible in the ordinary spectrum of hydrogen, may be found among the lines of that other spectrum of many lines which Plücker has recorded (Phil. Trans. for 1865, p. 22. § 60).

A more detailed examination of the foregoing theory raises the hope that it will throw light from various directions upon molecular motions.

Experiments on Colour.

By the Hon. J. W. Strutt, *Fellow of Trinity College, Cambridge.*

The author gave an account of some observations with the colour-disks, and on the disturbance produced by looking through coloured solutions at the match first adjusted by the naked eye. A difference in the colour-equations was also noticed according to whether the light came from the blue sky or from clouds. Some remarks followed on the nature of the compound yellow; and a method of obtaining it was described more convenient in many cases than the use of the spectral rays isolated by the prism. Mixtures of either an alkaline infusion of litmus or a solution of sesquichloride of chromium with the chromate of potash isolate the green and red portions of the spectrum, cutting out the yellow and orange which lie between them. In suitable proportions, either of them give a very full compound yellow, which is yet almost entirely free from any yellow-looking elementary light.

On two Spectra of Carbon existing at the same Temperature. *By* W. M. Watts.

In this paper the author gave an account of his attempt to ascertain whether the two totally different spectra of carbon depend on a difference of temperature. The No. 1 spectrum is that given by olefiant gas or carbonic oxide and various other compounds of carbon, either when burnt in air or oxygen or by means of the electric spark at ordinary pressures.

The No. 2 spectrum is produced only by the electric spark *in a vacuum*, and is given under such circumstances either by olefiant gas or carbonic oxide. The temperature of the flames producing the No. 1 spectrum varies from below 2000° C. to 10,000° C., whilst by enclosing vapour of sodium in the Geissler tube giving the No. 2 spectrum, the author found that at first the line D showed, which comes out below 2000° C., and afterwards, as the tube was heated, Na β, which indicates a temperature of about 2000° (as it is produced in flames which just melt platinum), and finally Na γ (which does not appear till 3000° C).

During these changes the carbon No. 2 spectrum remained unaltered; the author concludes therefore that both spectra are equally producible by temperatures of between 2000° and 3000° C., and that the difference between them, whatever its cause, does not depend upon temperature.

CHEMISTRY.

Address by Professor Henry E. Roscoe, *B.A., Ph.D., F.R.S., F.C.S., President of the Section.*

Gentlemen,—

In the midst of the excitement of the horrible war in which the two most scientific nations of the Continent are now plunged, and in which even the professors of chemistry and their students take a humane part, let us endeavour to turn our thoughts into channels more congenial to the scientific inquirer, and allow me to recount to you, as far as I am able, the peaceful victories which, since our last Meeting, in Exeter, have been achieved in our special department of Chemistry. And here may I be allowed to remind you of the cosmopolitan character of science, of the fact that it is mainly to the brotherly intercourse of those interested in science, and in its applications to the arts and manufactures in different countries, that we ought to look for the small but living fire which in the end will surely serve to melt down national animosities, and to render impossible the breaking out of disasters so fatal to the progress of science and to the welfare of humanity as that of which we are now unfortunately the spectators.

With regard to the position of chemical science at the present moment, it will not take a careful observer long to see that, in spite of the numerous important and brilliant discoveries which every year has to boast, we are really but very imperfectly acquainted with the fundamental laws which regulate chemical actions, and that our knowledge of the ultimate constitution of matter upon which these laws are based is but of the most elementary nature. In proof of this I need only refer to the different opinions expressed by our leading chemists in a discussion which lately took place at the Chemical Society on the subject of the Atomic Theory. The President (Dr. Williamson) delivered an interesting lecture, in which the existence of atoms was treated as "the very life of chemistry." Dr. Frankland, on the other hand, states that he cannot understand action at a distance, and therefore he cannot comprehend the discontinuity of matter, an idea lying at the base of the notion of atoms. Sir B. C. Brodie and Dr. Odling both agree that the science of chemistry neither requires nor proves the atomic theory; whilst the former points out that the true basis of the science is to be sought in the investigation of the laws of gaseous combination, or the study of the capacity of

bodies for heat rather than in committing ourselves to assertions incapable of proof by chemical means.

Agreeing in the main with the opinion of the last two chemists, and believing that we must carefully distinguish between fact and theory, I would remind you that Dalton's discovery of multiple and reciprocal proportions (I use Dr. Odling's word), as well as the differences which we now acknowledge in the power of hydrogen-replacement in hydrochloric acid, water, ammonia, and marsh-gas, are *facts*, whilst the explanation upon the assumption of atoms is, as far as chemistry has yet advanced, a *theory*. If, however, the existence of atoms cannot be proved by chemical phenomena, we must remember that the assumption of the atomic theory explains chemical facts as the undulatory theory gives a clear view of the phenomena of light; thus, for instance, one of the most important facts and relations of modern chemistry which it appears difficult, if not impossible, to explain without the assumption of atoms is that of Isomerism. How otherwise than by a different arrangement of the single constituent particles are we to account for several distinct substances in which the proportions of carbon, hydrogen, and oxygen are the same? Why, for instance, should 48 parts, by weight, of carbon, 10 of hydrogen, and 16 of oxygen, united together, be capable of existing as three different chemical substances, unless we presuppose a different statical arrangement of the parts by which these differences in the deportment of the whole are rendered possible?

Although chemistry appears not to be able to give us positive information as to whether matter is infinitely divisible, and therefore continuous, or whether it consists of atoms and is discontinuous, we are in some degree assisted in this inquiry by deductions from physical phenomena recently pointed out by the genius of Sir Wm. Thomson. This philosopher, arguing from four distinct classes of physical phenomena, not only comes to the conclusion that matter is discontinuous, and therefore that atoms and molecules do exist, but he even attempts to form an idea of the size of these molecules; and he states that in any ordinary liquid or transparent or seemingly opaque solid, the mean distance between the centres of contiguous molecules is less than the hundred-millionth, and greater than the two-thousand-millionth of a centimetre. Or, to form a conception of this coarse-grainedness, imagine a raindrop, or globe of glass as large as a pea, to be magnified up to the size of the earth, each constituent molecule being magnified in the same proportion, the magnified structure would be coarser-grained than a heap of small shot, but probably less coarse-grained than a heap of cricket-balls.

There is, however, another class of physical considerations which render the existence of indivisible particles more than likely. I refer to the mechanical theory of gases, by means of which, thanks to the labours of eminent English and German philosophers, all the physical properties of gases (their equal expansion by heat—the laws of diffusion—the laws of alteration of volume under pressure) can be shown to follow from the simple laws of mechanical motion. This theory, however, presupposes the existence of molecules; and in this direction again we find confirmation of the real existence of Dalton's atoms. Indeed it has been proved that the average velocity with which the particles of oxygen, nitrogen, or common air are continually projected forwards amounts, at the ordinary atmospheric pressure, to 50,000 centimetres per second, whilst the average number of impacts of each of these molecules is 5000 millions per second.

The mention of the molecular motions of gases will recall to the minds of all present the great loss which English science has this year sustained in the death of the discoverer of the laws of gaseous diffusion. Throughout his life Graham's aim was the advancement of our knowledge in the special subject of the molecular properties of gases. With this intent he unceasingly laboured up to the moment of his death, in spite of failing health and pressure of official business, unfolding for posterity some of the most difficult, as well as the most interesting, secrets of nature in this branch of our science. "What do you think," he writes to Hofmann, "of metallic hydrogen, a white magnetic metal?" and yet now through his labours the fact of the condensation of hydrogen in the solid state by metallic palladium, and to a less extent by other metals, has become familiar to all of us. Then, again, I would remind you of Graham's recent discovery of the occlusion of hydrogen

gas in certain specimens of meteoric iron, whilst earth-manufactured iron contains not hydrogen but absorbed carbonic oxide gas—proving that the meteorite had probably been thrown out from an atmosphere of incandescent hydrogen existing under very considerable pressure, and therefore confirming in a remarkable degree the conclusions to which spectrum analysis had previously led us. The position in the ranks of British science left by Graham's death will not be easily filled up: he accomplished, to a certain extent, for dynamical chemistry what Dalton did for statical chemistry; and it is upon his experimental researches in molecular chemistry that Graham's permanent fame as one of England's greatest chemists will rest.

As closely connected with the above subjects, I have next to mention a most important research by Dr. Andrews, of Belfast, which, marking an era in the history of gases, shows us how our oldest and most cherished notions must give way before the touchstone of experiment. No opinion would appear to have been more firmly established than that of the existence of three separate states or condition of matter, viz. the solid, the liquid, and the gaseous. A body capable of existing in two or more of these states was thought to pass suddenly from one to the other by absorption or emission of heat, or by alterations of the superincumbent pressure. Dr. Andrews has shown us how false are our views on this fundamental property of matter; for he has proved that a large number of, and probably all, easily condensible gases or vapours possess a critical point of temperature at and above which no increase of pressure can be made to effect a change into what we call the liquid state, the body remaining as a homogeneous fluid, whilst below this critical temperature certain increase of pressure always effects a separation into two layers of liquid and gaseous matter. Thus with carbonic acid the point of critical temperature is 30°·92 C.; and with each given substance this point is a specific one, each vapour exhibiting rapid changes of volume and flickering movements when the temperature or pressure was changed, but showing no separation into two layers. Under these circumstances it is impossible to say that the body exists either in the state of a gas or of a liquid; it appears to be in a condition intermediate between the two. Thus carbonic acid under the pressure of 108 atmospheres, and at 35°·5 C., is reduced $\frac{1}{430}$ of the volume which it occupies at one atmosphere; it has undergone a regular and unbroken contraction, and it is a uniform fluid; if we now reduce the temperature below 31° C., the liquid condition is assumed without any sudden change of volume or any abrupt evolution of heat. We can scarcely too highly estimate the value of these researches of Dr. Andrews.

As examples of the power which modern methods of research give of grappling with questions which only a few years ago were thought to be insoluble, I may quote the beautiful observations, now well-known, by which Lockyer determined the rate of motion on the sun's surface—together with those of Frankland and Lockyer respecting the probable pressure acting in the different layers of the solar atmosphere, and, lastly, the results obtained by Zöllner respecting the probable absolute temperature of the sun's atmosphere, as well as that of the internal molten mass. These last results are so interesting and remarkable, as being arrived at by the combination of recent observation with high mathematical analysis, that I may perhaps be permitted shortly to state them.

Starting from the fact of the eruptive nature of a certain class of solar protuberances, Zöllner thinks that the extraordinary rapidity with which these red flames shoot forth proves that the hydrogen of which they are mainly composed must have burst out from under great pressure; and if so, the hydrogen must have been confined by a zone or layer of liquid from which it breaks loose. Assuming the existence of such a layer of incandescent liquid, then applying to the problem the principles and methods of the mechanical theory of gases, and placing in his formulæ the data of pressure and rate of motion as observed by Lockyer on the sun's surface, Zöllner arrives at the conclusion that the difference of pressure needed to produce an explosion capable of projecting a prominence to the height of 3·0 minutes (=80,000 English miles) above the sun's surface (a height not unfrequently noticed) is 4,070,000 atmospheres. This enormous pressure is attained at a depth of 139 geographical miles under the sun's surface, or at that of

one 658th part of the sun's semidiameter. In order to produce a tension capable of overcoming this gigantic pressure, the difference in temperature between the enclosed hydrogen and that existing in the solar atmosphere must be 74,910° C.! In a similar way Zöllner calculates the approximate absolute temperature of the sun's atmosphere, which he finds to be 27,700° C., a temperature about eight times as high as that given by Bunsen for the oxyhydrogen flame, and one at which iron must exist in a permanently gaseous form.

Passing on to more purely chemical subjects, we find this year signalized by the redetermination of a most important series of chemical constants (that of the heat of chemical combination) by Julius Thomsen, of Copenhagen. This conscientious experimentalist asserts that the measurements of the heat evolved by neutralizing acids and bases hitherto considered most correct, viz. those made with a mercury calorimeter by Favre and Silbermann, differ from the truth by 12 per cent., whilst the determination by these experimenters of the heat of solution of salts is frequently 50 per cent. wrong.

As the result of his numerous experiments, Thomsen concludes that, when a molecule of acid is neutralized by caustic alkali, the heat evolved increases nearly proportionally to the quantity of alkali added, until this reaches 1, $\frac{1}{2}$, $\frac{1}{3}$, or $\frac{1}{4}$ of a molecule of alkali, accordingly as the acid is mono-, bi-, tri-, or tetrabasic. Exceptions to the law are exhibited by silicic, and also partly by boracic, orthophosphoric, and arsenic acids. In the two latter the heat of combination is proportional for the first two atoms of replaceable hydrogen, but much less for the third atom. A second unexpected conclusion which Thomsen draws from his calorific determinations is that sulphuretted hydrogen is a monobasic acid, and that its rational formula is therefore H (S H).

Another important addition made to chemistry since our last Meeting is a new, very powerful, and very simple form of galvanic battery discovered, though not yet described, by Bunsen. In this second Bunsen's battery only one liquid, a mixture of sulphuric and chromic acids, is employed. The plates of zinc and carbon can all be lowered at once into the liquid and raised again at will. The electromotive force of this battery is to that of Grove's (the most powerful of known forms) as 25 to 18; it evolves no fumes in working, and can be used for a very considerable length of time without serious diminution of the strength of the current; so that Bunsen writes me that no one who has once used the new battery will ever think of again employing the old forms. I had hoped to be able to exhibit to the Section this important improvement in our means of producing a strong current; but war has demanded the use of other batteries, and Bunsen has been unable to send me a set of his new cells.

Amongst the marked points of interest and progress in Inorganic chemistry during the past year we have to notice the preparation of a missing link amongst the oxysulphur acids by Schutzenberger. It is the lowest known, and may be called hydrosulphurous acid, $H_2\ SO_2$. The sodium salt, $Na\ H\ SO_2$, is obtained by the action of zinc on the bisulphite; as might be expected, it possesses very powerful reducing properties, and bleaches indigo rapidly.

The metallic vanadates have also been carefully examined, and the existence of three distinct series of salts proved, corresponding to the phosphates, viz. the ortho- or tribasic vanadates, the pyro- or tetrabasic vanadates, and the meta- or monobasic vanadates. Of these the ortho-salts are most stable at a high temperature, and at the ordinary atmospheric temperature the meta-salts are most stable, whilst, as is well known, in the phosphorus series the order of stability is the reverse. Thus the points of analogy and of difference between phosphorus and vanadium become gradually apparent.

As an illustration of the results of modern Organic research (for in viewing the year's progress in this ever widening branch of chemistry it is impossible to do more than give a few illustrations), I may quote Baeyer's remarkable investigations on mellitic acid. Originally discovered by Klaproth in Honeystone or Mellite (a substance which yet remains the only source of the acid), mellitic was supposed to be a 4-carbon acid. Baeyer has quite recently shown that the acid contains twelve atoms of carbon, or has a molecular weight three times as great as was originally supposed. He has shown that mellitic acid is benzol hexacarbonic

acid, $C_{12}H_6O_{12}$, or benzol in which the 6 atoms of hydrogen are replaced by the monad radical carboxyl (CO OH), as benzoic is monocarbonic acid, or benzol in which one of hydrogen is replaced by carboxyl. The most interesting portion of Baeyer's research, however, lies in the intermediate acids, partly new and partly acids already prepared, which he has shown lie between mellitic and benzoic, and in which from one to six atoms of hydrogen in benzol are respectively replaced by carboxyl. Nor is this all; for he has proved that, with two exceptions, each of these six acids is capable of existing in three isomeric modifications, thus affording us an insight into the arrangement of the molecule of these aromatic compounds; for the simplest mode of explaining these numerous isomers is that given by Baeyer, in the different order in which the several atoms of hydrogen in the benzol molecule are replaced. Thus in the first or ortho-series, the hydrogen atoms in benzol being numbered in regular succession, they are replaced in the same regular succession. In the second or meta series the order is 1, 2, 3, 5, &c., whilst the third or para-series take open order, as 1, 2, 4, 5, &c.

Thus we have:—

		Ortho-series.	Para-series.	Meta-series.
$C_{12}H_6O_{12}$	Hexabasic.	Mellitic or benzol hexacarbonic.		
$C_{11}H_6O_{10}$	Pentabasic.	Unknown.		
$C_{10}H_6O_8$	Tetrabasic.	Pyromellitic or benzol tetracarbonic.	Isopyromellitic.	Unknown.
$C_9H_6O_6$	Tribasic.	Trimesinic or benzol tricarbonic.	Hemimellitic.	Trimellitic.
$C_8H_6O_4$	Dibasic.	Phthalic or benzol dicarbonic.	Isophthalic.	Tetraphthalic.
$C_7H_6O_2$	Monobasic.	Benzoic or benzol monocarbonic.		

Amongst the most interesting series of new organic bodies are those in which tetrad silicon partly replaces carbon. Our knowledge of these substances is gradually becoming more complete; the last new member prepared by Friedel and Ladenburg, is silico-propionic acid, $\begin{matrix}C_2H_5\\SiO_2H\end{matrix}$, the first of a series of carbo-silicic acids containing the radical SiO_2H.

The interesting researches of Matthiessen and Wright on morphine and codeine have thrown a new light on the constitution of these opium alkaloids. Treated with hydrochloric acid, morphine loses one molecule of water, and gives rise to a new base, apomorphine,

$$\underset{\text{Morphine.}}{C_{17}H_{19}NO_3} = H_2O + \underset{\text{Apomorphine.}}{C_{17}H_{17}NO_2},$$

which differs in a remarkable manner from morphine, both in its chemical and physiological actions, being soluble in alcohol, ether, and chloroform, whereas morphine is nearly insoluble, and acting as the most powerful emetic known, $\frac{1}{10}$ of a grain producing vomiting in less than ten minutes. Codeine, which only differs from morphine by CH_2, also yields apomorphine on treatment with hydrochloric acid, methylchloride being at the same time eliminated.

An important application of the dehydrating and carbon-condensing power of zinc chloride, long known in its action on alcohol to produce ether, has been made by Kekulé in the reduplication of aldehyde to form croton aldehyde with loss of water, $2\,(C_2H_4O) - H_2O = C_4H_6O$. This croton aldehyde is also probably formed as an intermediate product in the manufacture of chloral from aldehyde, and gives rise to the formation of croton chloral, $C_4H_3Cl_3O$.

The discovery of the sedative properties of chloral-hydrate by Leibreich marks an era in medical chemistry second only to the discovery of the anæsthetic properties of chloroform. Chloral not only combines with water to form a solid hydrate, but also forms solid alcoholates; but these bodies appear to possess quite different medicinal properties from the hydrate, and it is important that no alcoholate should be present.

The chemistry of colouring-matter has lately received an enormous impetus in

the practical working of the memorable discovery of the production of artificial alizarine, the colouring-matter of madder, by MM. Graebe and Liebermann. This discovery, announced at our last Meeting, is of the highest importance, whether we regard its scientific interest or its practical and commercial value; and it differs from all the former results which have been brought about by the application of science to the production of colouring-matters, inasmuch as this has reference to the artificial production of a natural vegetable colouring substance which has been used as a dye from time immemorial, and which is still employed in enormous quantities for the production of the pink, purple, and black colours which are seen everywhere on printed calicoes.

During the past year much progress has been made in the practical working of the processes by which this colouring-matter is obtained from the hydrocarbon anthracene contained in coal-tar; and new and more economical plans for effecting the transformation have been independently proposed by Perkin and Caro, and Schorlemmer and Dale. The theoretical investigation of the reaction, and especially of the nature of some other peculiar products in addition to alizarine which render the artificial colouring-matter different from the natural colour, has been carried out by Mr. Perkin and by Dr. Schunck. As we are promised papers on this subject from both these gentlemen, I need not at present enter further into these interesting questions.

The surest proof of perfection in a manufacture is the degree in which the waste products are utilized, and in which the processes are made continuous. One by one the imperfections of the original discovery are made to disappear, the products which were wasted become sources of profit; and in many cases their utilization alone renders possible the continuance of the manufacture in the middle of a rapidly increasing district. The Section will have the opportunity of inspecting the practical working of at least two of the most valuable of these new processes. The first of these has been at work for some time; it is that of the recovery of the sulphur from the vat-waste, that *bête noire* of the alkali-makers and of their neighbours. Dr. Mond has now satisfactorily solved the difficult problem of economically regaining the sulphur by oxidizing the insoluble monosulphide of calcium to the soluble hyposulphite, and decomposing this by hydrochloric acid, when all the sulphur is deposited as a white powder.

The second of these discoveries relates to the recovery or regeneration of the black oxide of manganese used for the evolution of chlorine in the manufacture of bleaching-powder. This subject has long attracted the attention of chemists; and a feasible though somewhat costly process, that of Dunlop, has been at work for some time at Messrs. Tennant's works at St. Rollox. During the last year a very beautifully simple and economical process, proposed by Mr. Weldon, and first successfully carried out on a practical scale in Messrs. Gamble's works at St. Helens, has quickly obtained recognition, and is now worked by more than thirty-seven firms throughout the kingdom.

The principle upon which this process depends was explained by Mr. Weldon at the Exeter Meeting. It depends on the fact that although when alone the lower oxides of manganese cannot be oxidized by air at the ordinary temperature and under the ordinary pressure to the state of dioxide, yet this is possible when one molecule of lime is present to each molecule of the oxide of manganese. The manganous oxide is precipitated from the still-liquors with the above excess of lime; and by the action of air on this a black powder, consisting of a compound of manganese dioxide and lime, MnO_2 CaO, or calcium manganite, is formed. This of course is capable of again generating chlorine on addition of hydrochloric acid; and thus the chlorine process is made continuous, with a working loss of only $2\frac{3}{4}$ per cent. of manganese. The Section will have the advantage of seeing Mond's process at work at Messrs. Hutchinson's, and Weldon's process at Messrs. Gaskell, Deacon and Co.'s at Widnes.

A third process, which may possibly still further revolutionize the manufacture of bleaching-powder, is the direct production of chlorine from hydrochloric acid without the use of manganese at all. In the presence of oxygen and of certain metallic oxides, such as oxide of copper, hydrochloric acid gas parts at a red heat with all its hydrogen, water and chlorine being formed. This interesting reaction is employed

by its discoverer, Mr. Deacon, for the direct manufacture of bleaching-powder from the gases issuing directly from the salt-cake furnace. Air is admitted, together with hydrochloric acid gas, and the mixture is passed over red-hot bricks impregnated with copper salt. The oxide of copper acts as by contact and remains unaltered, whilst the chlorine, watery vapour, and excess of air pass at once into the lime-chamber. There are many practical difficulties in working this process on the large scale, some of which have still to be overcome; but I believe we shall hear from Mr. Deacon that, notwithstanding these drawbacks, he has accomplished his end of making good bleaching-powder by this process.

On the Alloys of Copper, Tin, Zinc, Lead, and other Metals with Manganese. By J. Fenwick Allen, *F.C.S.*

In the year 1826 a spoon, made by Messrs. Zernecke, of Berlin, was analzyed, and the alloy was found to be composed of copper 57·1 per cent., manganese 19·7 per cent., zinc 23·2 per cent. This analysis is included in a chapter on Kupfermangan, by Mr. Johann Tenner, in his 'Handbuch der Metall-Legirungen,' published at Quedlinburg. Berthier produced a large number of alloys of manganese with various metals, and has recorded their principal properties.

Whilst, therefore, the alloys of copper, zinc, and other metals with manganese have been more or less known to the metallurgist for more than forty years, whilst their valuable physical properties have been fully described, whilst, moreover, manganese in its ores almost approaches iron in its abundance and in its value, and yet for years has been suffered to escape as a waste product from almost every large alkali-works, we find the metallurgist has not succeeded in reducing it to serve widely except when yoked with iron.

To produce metallic manganese was not from the first attempted; and it is with extreme difficulty that even small quantities of this metal can be prepared.

From the first it was discovered that in using any of the ores of manganese, the iron and the silicon completely destroyed the value of the product. Having obtained a comparatively pure oxide of manganese, recovered from the "still liquors," and having mixed this with oxide of copper (*not metallic copper*), together with wood charcoal, all finely ground and intimately mixed, the charge was put into a plumbago crucible, then heated in an air-furnace at an intense heat from three to four hours. When the pot was taken out, it was found that, still suspended in the charcoal, and not run down to the bottom, there were innumerable fine shots of a bright white metal; these, being separated by washing and placed again in the crucible and heated, fused into a pill or button covered with a layer of green vitreous slag. The process was continued until some small ingots were produced; and on these experiments were made as to their malleability and ductility.

The alloy was found to be very hard and very brittle when hot; but when cold, although still hard, it rolled with ease, and was highly elastic. The proportions of the alloy were about:—copper 75 per cent., manganese 25 per cent. When the simple alloy had been produced in sufficient quantities, compound alloys with zinc were tried in various proportions; and these, again, rolled with complete success.

Certain mixtures of copper, zinc, and manganese possess the advantage over both German silver and yellow metal, that, whereas the one will only roll cold and the other hot, the manganese alloy rolls from hot to cold.

As a simple alloy, in which the proportions of manganese range from 5 to 30 per cent., it is both malleable and ductile, with a tenacity considerably greater than that of copper.

With zinc a compound alloy, resembling in some of its qualities German silver, is obtained.

The alloy of copper and manganese combines with tin, lead, and other metals; and from these castings are made, and applied as bearings for machinery, and other similar purposes.

It was not the nature of the metal itself that prevented it being widely used; it was its cost. The waste of manganese is very considerable, over 10 per cent. remaining unreduced, and forming a silicate; the wear and tear of the plumbago

pots and the furnace incurred a large expense; and in proportion to the quantity of metal produced, the fuel consumed and the labour expended were great.

The waste of manganese in alloys rich in that metal will, it is feared, always be considerable; but the value of the raw material would permit some such loss, could the other points be obtained; and these, it is believed, have now been achieved.

The metal has been produced by heating a mixture of carbonate of manganese with oxide of copper and charcoal in a tolerably large reverberatory furnace, and not in a small and costly pot. The fuel used has been principally the common slack or small coal of the district, and not coke. The labour has been proportionately reduced; and a series of alloys are produced that ere long promise to play no unimportant part in the arts and manufactures.

It is the excellent furnace-arrangements of Mr. Siemens that have assisted in overcoming the difficulties at first encountered, by affording the intense heat needed, with a non-oxidizing flame, in a quiet atmosphere.

The following specimens were exhibited:—

1st. Manganese and copper, in various proportions from 35 to 5 per cent. of manganese, as ingot, sheet, and wire.

2nd. Copper, zinc, and manganese; also in different proportions, and in a variety of applications.

3rd. Copper, zinc, manganese, and tin; as ingots and as bearings.

4th. Copper, manganese, and tin, in several different proportions; as bars.

5th. Copper, manganese, and lead.

On the Chemical Composition of the Bones of General Paralytics.
By J. Campbell Brown, *D.Sc.*

Constituents.	I. Ribs of General Paralytics.	II.	III.	IV.	V. Nine Months' Fœtus.	VI. Osteomalacia.	VII. Adult Tibia (Valentin).	VIII. Adult Ribs (Von Bibra).
Phosphoric acid	....	22·85	19·09	23·52	23·31	16·89	24·24	25·95
Lime	....	28·54	25·25	29·57	28·98	22·20	32·98	34·43
Magnesia and alkalies	....	·43	·37	·41	·36	1·05	1·37	1·67
Carbonic acid	....	1·29	2·09	1·55	1·10	1·71	3·37	2·90
Total inorganic constituents	49·46	53·11	46·8	55·05	53·75	41·85	61·96	64·95
Organic constituents	50·54	47·02	53·5	44·84	47·15	58·16	38·02	33·97
	100·00	100·13	100·3	99·89	100·90	100·01	99·98	*98·92
Ratio of lime to phosphoric acid		$\frac{88}{71}$	$\frac{93}{71}$	$\frac{89}{71}$	$\frac{88}{71}$	$\frac{92}{71}$	$\frac{97}{71}$	$\frac{94}{71}$

I. shows the average proportions of organic and earthy matter in several samples, which were remarkable only for being less perfectly developed than the ribs of healthy adults; some of these had been fractured and perfectly united; others were entire.

II. These ribs were not fractured, nor did they contain much fat; but they were thinner than usual.

III. consisted of one rib only; it was slender, and rough and jagged on the edges, but had not been fractured.

IV. consisted of six ribs, which had all been fractured, and had completely united, and showed a slight callosity; some of them had been again fractured more

* This specimen also contained fat which had not been removed before analysis.

recently, and had only imperfectly united; they contained an unusual amount of fat. Portions of the ribs were removed and freed from fat before they were submitted to analysis, and the remaining portions were handed to the Curator of the Museum of the School of Medicine.

V. For comparison with these, I give the composition of the femur and tibia of a nine months' fœtus in column V., and of the bones from a case of osteomalacia in column VI.

VII. is calculated from the analysis of a healthy adult tibia by Valentin.

VIII. is calculated from analyses of ribs of a healthy man, aged 25, by Von Bibra.

It will be observed that the ratio of organic constituents to earthy matter is much greater, while the ratio of lime to phosphoric acid is distinctly less, in the ribs of paralytics than in those of healthy adults. There are the same differences between the composition of healthy ribs and those of paralytics as between the composition of the adult large bones and those of the fœtus; and, generally, the composition in cases of paralysis approaches that observed in cases of osteomalacia. Whether the defects in the ribs of paralytics are due to arrested development or to degeneration of the fully developed bone, it will require further experiments upon carefully selected cases to prove; but from the evidence already obtained the author was led to conjecture that both causes will be found to operate.

The result of the analysis is suggestive rather than conclusive as to the condition of the bones in patients the subjects of general paralysis; and it would be unsafe to generalize from a few examples. The analysis, however, is a first instalment towards determining, by scientific inquiry, whether the statements that have been made, as to the peculiar liability to fracture of the bones in certain forms of insanity, holds good as a general rule.

On a Spectroscope in which the Prisms are automatically adjusted for the Minimum Angle of Deviation for the particular Ray under examination. By JOHN BROWNING, *F.R.A.S.*

In spectroscopes of ordinary construction, when several prisms are employed, a great deficiency of light will be noticed towards the more refrangible end of the spectrum.

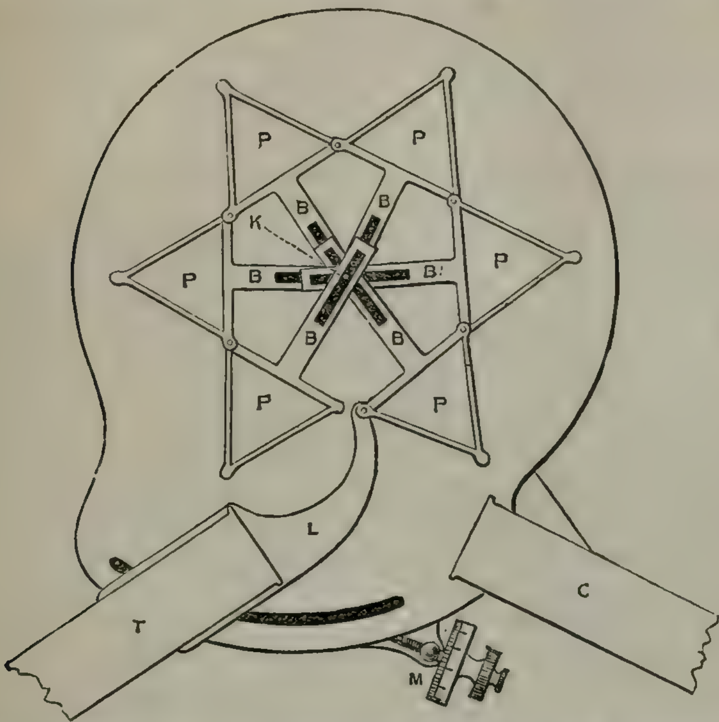
This arises from the fact that the prisms are adjusted to the minimum angle of deviation for the most luminous rays, which are near the other end of the spectrum.

The Diagram shows the method in which the change in the adjustment of the prisms to the minimum angle of deviation for each particular ray is made automatically. In this diagram P, P, &c. represent prisms. All these prisms, with the exception of the first, are unattached to the plate on which they stand—the triangular stand, on which the prisms are hinged together at the angles corresponding to those at the bases of the prisms; to each of these bases is attached a bar B, perpendicular to the base of the prism. As all these bars are slotted, and run on a common centre, the prisms are brought into a circle. This central pivot is attached to a dovetail piece, two or three inches in length, placed on the underside of the main plate of the spectroscope, which is slotted to allow it to pass through. On moving the central pivot the whole of the prisms are moved, each to a different amount, in proportion to its distance in the train from the first or fixed prism, on which the light from the slit falls after passing through the collimator C. Thus, supposing* the first prism of the train from C, represented in the diagram, to be stationary, and the second prism to have been moved through 1° by this arrangement, then the third prism will have moved through 2°, the fourth through 3°, the fifth through 4°, and the sixth through 5°. As these bars are at right angles to the bases of the prisms, and all of them pass through a common centre, it is evident that the bases of the prisms are at all times tangents to a common circle.

Now for the contrivance by which this arrangement is made automatic. A lever L is attached to the corner of the triangular plate of the last prism; this lever, by its further end, is attached to the support which carries the telescope through which the spectrum is observed. Both the telescope and lever are driven by the

* It really has a slight movement round one angle.

micrometer-screw M. The action of the lever is so adjusted that, when the telescope is moved through any angle, it causes the last prism to turn through double that angle. The rays which issue from the centre of the last prism are thus made



to fall perpendicularly upon the centre of the object-glass of the telescope T; and thus the ray of light travels parallel to the bases of the several prisms, and ultimately along the optical axis of the telescope itself, and thereby the whole field of the object-glass is filled with light.

Thus the apparatus is so arranged that, on turning the micrometer-screw so as to make a line in the spectrum coincide with the cross wires in the eyepiece of the telescope, the lever L, attached to the telescope and prisms, sets the whole of the prisms in motion, and adjusts them to the minimum angle of deviation for that portion of the spectrum.

On the Examination of Sea Water on board H.M.S. 'Porcupine,' in July 1870, for dissolving Gases and varying proportions of Chlorine. By W. Lant Carpenter.

Contributions to Mineralogical Chemistry. By A. H. Church, *M.A., F.C.S.*

Experiments on the Preservation of Stone. By A. H. Church, *M.A., F.C.S.*

On the Purification of Public Thoroughfares by the application of Deliquescent Chlorides. By W. J. Cooper.

The author had first called attention to the subject in 1868; at that time a very successful experiment had been tried in Baker Street, Portman Square. In Liverpool, in 1869, Bold Street, Church Street, and Lord Street were watered with salts during the month of July. The report of the result was very favourable, and the experiments have been continued this year. In many towns experiments have been tried during the past season, with various results, according to tl e composi-

tion of the roadways. It is difficult to prove the economy resulting from the use of the chlorides over a limited area; but over large areas it is very evident. The importance, in a sanitary point of view, of the use of chlorides has been clearly established. The chloride of calcium decomposes the carbonate of ammonia contained in the horse-droppings, the results being carbonate of lime and chloride of ammonium, which two results, combining with the chloride of sodium and the carbonate of lime contained in the roadway, cause the concreting effect so important in the prevention of dust and the preservation of the roads.

A new Chlorine Process without Manganese (with illustrations). *By* HENRY DEACON.

A heated mixture of hydrochloric acid gas and oxygen or air are passed over heated salts of copper, lead, or manganese, or pieces of burnt clay, or similar porous bodies previously soaked in solutions of the salts. Under these circumstances the chlorine of the hydrochloric acid is set free; and the action is so complete that, by proportioning the surfaces of the salts and current of gases, the whole of the chlorine can be liberated or all the oxygen or air absorbed. At 750° F. the reaction is most active with copper salts; lead salts require a higher temperature, and manganese salts still higher; and as the temperatures increase, it is believed chlorine reacts on the vapour of water produced to re-form hydrochloric acid. With copper salts no such re-formation occurs. If the temperature be too high, chloride of copper always sublimes, whatever salt of copper be first employed.

The author predicted this reaction, so far as the chloride of copper and of manganese are concerned, from the belief that chemical forces may be united and resolved as mechanical forces are, and as, he believes, is evidenced in the ordinary manufactures of sulphuric acid and of sulphuric ether by the continuous processes.

The positive proof or disproof of this theory appears only to be possible by considering the time occupied. If a result follows from the formation and subsequent decomposition of a compound, the total time will be the time of the two processes added together; but if it be a direct result of the union of the forces, it will be the time only of either process alone. This proof being at present unavailable, the author relies on the test of the other proof of a correct theory, viz. its power of foretelling unknown events, and claims in this instance to have shown the great probability of the truth of his theory, admitting that it is not yet strictly proved.

Note on Thermal Equivalents.—1. *Fermentation.* 2. *Oxides of Chlorine.* *By* JAMES DEWAR, *F.R.S.E.*

On Cyanogen. *By* THOMAS FAIRLEY, *F.C.S., Science Master at the Leeds Grammar School.*

I. *Preparation of Cyanogen.*—The author has found the most convenient method for the preparation of cyanogen to be the action of one part of pure potassium cyanide, dissolved in as little water as possible, on two parts of powdered copper sulphate, mixed with scarcely more water than sufficient to moisten and cover it.

The operation may be performed in an ordinary bottle or flask; and the cyanide solution should be added a little at a time, as the action is very rapid. Much water prevents the action. Besides its convenience, this method gives at least two 15ths of the weight of the cyanide as cyanogen. Careful experiments, made with mercuric cyanide, show that it is very difficult to obtain more than one 15th of its weight as cyanogen, *i. e.* only one third of the cyanogen it contains.

II. *Hydrogenation of Cyanogen.*—In a former paper the author showed that when cyanogen and hydrogen are passed over platinum black at 140° C., they combine. He has repeated and extended these experiments, and finds that the substance obtained by passing the gases into dilute hydrochloric acid is the chloride of an organic base containing C, H, N, Cl in the exact proportions of the chloride of ethylene diammonium. The chloride is soluble in absolute alcohol, and, heated with alkalies, gives off a liquid base. The chlorplatinate is very soluble in water, and soluble to

some extent even in strong alcohol. In forming this salt, if platinum solution containing acids of nitrogen be used, chlorplatinate of ammonium is obtained. In using platinum black, dark-coloured products are formed, which partly remain with the platinum, and interfere with the process. The author has tried all the other forms of platinum, and they all act more or less; but finds that platinized charcoal is the best. He prefers cocoanut-shell charcoal, because of its greater absorptive power; but ordinary charcoal, containing the same proportion of platinum, 5 per cent., answers very well.

Hydrogen from dilute sulphuric acid and zinc is passed through a wash-bottle, then through a cyanogen-bottle (giving off cyanogen from the mixture mentioned above). The mixed gases pass then through a wash-bottle containing water, then through an empty bottle, then through a long calcium-chloride tube to dry them thoroughly. They then pass over the heated charcoal placed in a flask or in a tube bent into a convenient form, and heated in an air-bath to 190° to 200° C., according to the rapidity of the current of the gases.

When this apparatus is working, dense white fumes are seen in the Liebig's bulb containing dilute hydrochloric acid, through which the gases finally pass. With a sufficient excess of hydrogen, little cyanogen escapes unacted on; and the charcoal remains as efficient after some days' use as at first.

This platinized charcoal also serves well for the hydrogenation of hydrocyanic acid.

Ordinary charcoal possesses in some degree the property of causing the gases to combine at a temperature of 210° C.

III. *Cyanogen Hydriodate.*—This substance is obtained by bringing the two dry gases into contact—more conveniently by passing cyanogen into dry ether, and then saturating it with dry hydriodic acid gas. It crystallizes out during the process. It has a reddish-yellow colour and onion-like smell, and stains the skin, paper, &c. dark brown. It absorbs moisture from the air with avidity, and is decomposed by water and by alcohol. From the aqueous solution the iodine is entirely precipitated by argentic nitrate. It is dried and freed from ether by passing over it a current of dry hydrogen while the flask containing it is placed on the water-bath. Heated above 100° C. it decomposes, giving off free iodine. Analyses give percentages agreeing well with the formula $C_2\,N_2\,H_2\,I_2$.

A compound containing more H I than the above exists, but is exceedingly unstable, continually losing hydriodic acid at ordinary temperatures.

These substances were obtained while experimenting on the hydrogenation of cyanogen by the action of metals on cyanogen and excess of hydriodic acid in etherial solutions.

Note on the Distillation of Sulphuric Acid. By Thomas Fairley, *F.C.S.*

In an attempt to obtain sulphuric anhydride by distilling sodium anhydrosulphate with strong sulphuric acid, the author observed the great facility with which sulphuric acid boils and distils in the presence of alkaline sulphates. By heating sulphuric acid and some alkaline sulphate over an ordinary Bunsen rose-burner, in a glass retort sheltered simply from draughts of cold air, quantities of pure sulphuric acid may be readily obtained. If the sulphuric acid contains acids of nitrogen, as it should do when an acid free from arsenic is required, these come over first, along with any water that may be present. Lead sulphate crystallizes out during the process, but does not interfere till it has accumulated from repeated operations.

On the Purification of Sankey Brook. By Alfred E. Fletcher, *F.C.S.*

The Sankey Brook flows through St. Helens, in Lancashire. Its chief impurities are free acid and sulphide of hydrogen.

The author proposes to allow the water to flow over beds of the old alkali waste, which is to be found in immense quantities in the neighbourhood.

This, containing hyposulphite of calcium, would give off sulphurous acid when dissolved in the acid water of the brook, and thus destroy the sulphide of hydrogen, the two gases forming together sulphur and water; at the same time the lime would neutralize the free acid.

Air-pollution from Chemical Works. By ALFRED E. FLETCHER, *F.C.S.*

On the Utilization of Sewage, with special reference to the Phosphate Process. By DAVID FORBES, *F.R.S.*

It was stated that sewage irrigation was the only process which had as yet utilized the entire liquid as well as the solid contents of the sewage. As, however, there are many cases in which sewage irrigation is neither applicable nor advantageous, it is desirable that some chemical process should be sought for by which the sewage could be so far purified by precipitation that the supernatant water could be allowed to run off directly into rivers without danger to health or animal life, whilst the precipitate should be of so high a value as manure as to pay for its transport to a distance for the use of the agriculturists. The experiments made already on the London sewage by the phosphate process, and on the present occasion successfully repeated on a small scale before the audience with Liverpool sewage, appear to fulfil in a great measure these conditions. This process, brought forward by the author in conjunction with Dr. A. Price, is based upon the fact that certain mineral phosphates, when in a freshly precipitated state, eagerly combine with both organic matter and ammonia in sewage. The process required nothing beyond a reservoir containing the sewage, to which the phosphates (in major part of alumina) are added, preferably in the state of solution in hydrochloric or sulphuric acid, from which, by the addition of a little milk of lime (just sufficient to neutralize the acid which holds them in solution), they are at once precipitated, along with the organic matter and part of the ammonia in the sewage. The deposit subsides rapidly, and leaves the water clear and colourless, even if tinctorial substances of great power are present: in the experiments shown, ink was added to the Liverpool sewage, but the colouring-matter was instantly removed along with the precipitate. The effluent water obtained by this process is, of course, not any thing like so pure as water ordinarily supplied for drinking-purposes; still the water from the London sewage at Barking Creek, so purified, could, as was shown, be drunk without repugnance, fishes could live in it, and it had remained free from offensive smell for months, during the entire hot summer of last year, without any tendency to putrefy or emit any disagreeable odour. With regard to the value of the precipitated manure, it was admitted that no known chemical substances could precipitate from sewage the whole amount of substances valuable for agriculture; and it was only claimed that so much of them had been extracted as to leave the effluent water innoxious, whilst one of the most important features of the process, in which it differs from all the others, is, that all the substances employed in the purification augment the agricultural value of the precipitated manure, and thus render it of such value as to enable it to bear the cost of transport to a distance.

On the Action of Sulphurous Acid, in Aqueous Solution, on Phosphates and other Compounds. By Dr. B. W. GERLAND.

Sulphurous acid in aqueous solution dissolves various phosphates without decomposing them, even when the oxide forms with sulphurous acid an insoluble compound. In this respect the tribasic phosphate of lime is particularly interesting. By means of sulphurous acid a solution of 1·3 sp. gr. can be obtained. This keeps very well in the cold; but a rise of the temperature to 19° determines the gradual precipitation of sulphite of lime. If the solution is quickly heated, a compound corresponding to the formula $3CO, PO_3, SO_2, 2HO$ is formed, which separates as a white crystalline powder, and is characterized by great stability. It is a powerful disinfectant and an active manure. The solution gives dibasic phosphate of lime by boiling under reduced pressure, by standing in vacuum, and by mixing with alcohol.

The dibasic phosphate of lime is also easily dissolved by sulphurous acid. The solution again deposits the original phosphate when the sulphurous acid is removed.

The phosphates of manganese and magnesia form strong solutions with sulphurous acid, from which the original phosphate can be again obtained. The phos-

phate-of-magnesia solution shows a great tendency to precipitate the dibasic phosphate, even if the tribasic salt is in solution. Phosphate of magnesia-ammonia is decomposed when used in excess, so that dibasic phosphate of magnesia is left in the residue.

The phosphate of copper is less soluble. The solution spontaneously deposits ruby-coloured crystals, $Cu_2 O SO_2 + CuO SO_2 + 2HO$; but when rapidly heated to the boiling-point, pure phosphate of copper is again formed.

Phosphate of uranium is sparingly soluble in water charged with sulphurous acid; and when the solution is heated the phosphate is again precipitated, with its original composition.

The crystals of tribasic phosphate of soda, $3NaO, PO_5 + 24HO$, absorb a current of SO_2 with great energy, heat is liberated, and the phosphate melts. After cooling, acid sulphite of soda crystallizes; and the remaining oily liquor is separated, by mixing with alcohol, into two layers, the lower being principally an aqueous solution of acid phosphate of soda, and the upper one an alcoholic solution of acid sulphite of soda. If the crystals of the phosphate are mixed with a little water and then saturated hot with SO_2, the clear solution separates, after standing, into two distinct layers, which unite again by shaking.

The phosphates of baryta, lead, and silver are decomposed by sulphurous acid into insoluble metallic sulphites and phosphoric acid, which is dissolved.

No other compound of sulphurous acid with a phosphate like the lime compound has been obtained.

The phosphates of stannic oxide, metastannic oxide, and bismuthic oxide are not acted on by sulphurous acid.

Arsenite of lime, prepared by precipitating ammoniacal solutions of arsenious acid and chloride of calcium, treated, when suspended in water, with sulphurous acid, gives a solution containing 3 eq. CaO and 1 eq. AsO_3, and arsenious acid is left undissolved. By boiling, the solution is decomposed into sulphite of lime, and arsenious acid remains in solution.

Vanadiate of copper forms a solution with water and sulphurous acid, which, when boiled, forms beautiful yellow metallic scales, containing copper, a lower oxide of vanadium, and sulphurous acid. They tarnish rapidly when exposed to the air.

Oxalate of lime is very sparingly soluble in water charged with sulphurous acid, and is deposited unchanged when the latter is driven out by heat.

Note on the Occurrence of Vanadium. *By* Dr. B. W. Gerland.

The author's friend, Mr. Jon. Donn, discovered a large deposit of a sandstone, the chemical analysis of which proved it to contain vanadiate of lead and copper, beside a great number of other metals, also thallium in appreciable quantity. The manufacture of vanadic acid from this ore is not difficult. The author has prepared 5¼ lbs. of pure vanadic acid from 1 cwt. of picked pieces of the sandstone.

Vanadic acid is likely to prove useful by its oxidizing property in both neutral and acid solutions. As the lower oxide of vanadium formed in this process is apt to take up oxygen from the air, the vanadic acid can play in solution the part of nitrous acid in the vitriol-chambers. For instance, a solution of 30 grms. of aniline in hydrochloric acid, mixed with 2 grms. ammonium vanadiate and much water, deposited, after some time, a deep-blue substance, which increased in quantity until all aniline had disappeared. The vanadiate was left in solution.

On Reciprocal Decomposition viewed with reference to Time. *By* John H. Gladstone, *F.R.S.*, *F.C.S.*

When solutions of two salts are mixed together, it has been found that they at once begin to decompose one another; but if the new compounds are themselves soluble in water, the decomposition is never complete, but the four salts remain together in solution in certain proportions, dependent on the strength of affinity of each base for each salt-radical, and on the actual amount of each. If, however, one of the new compounds is insoluble in water, it removes itself from the field of

action, and a redistribution of the constituents takes place, until the whole of the insoluble salt that can be formed is formed and precipitates. If one of the new compounds is so sparingly soluble that it crystallizes out, it is inferred that a further redistribution must also take place till the amount that the water holds in solution is sufficient to balance what remains of the original compounds. This is what has been termed "reciprocal decomposition."

In most cases that have been examined, this action takes place rapidly, the balance being attained apparently as soon as the salts are thoroughly mixed; in other cases, however, the action will go on for minutes, hours, or even days. Quantitative experiments had been made on the rate of formation of ferric meconate, ferric ferrocyanide in oxalic acid, potassio-iodide of platinum, the sulphates of barium, strontium, and calcium, oxalate of magnesium, and acid tartrate of potassium. It was found that where all four compounds remain in solution, the amount of new salt produced in equal periods of time becomes gradually less and less till the limit is very slowly attained; but where one of the new compounds crystallizes out, the maximum of chemical change is not at the commencement of the action but after a certain quantity of crystals have been already deposited. In this latter case many circumstances of a mechanical nature affect the rate, which do not influence the decomposition when all the compounds continue in solution; but a rise of temperature was found in both cases greatly to accelerate the chemical action.

On the Soda Manufacture. *By* W. Gossage.

This contribution was a supplement to a paper on the same subject read at Manchester in 1861, noticing various improvements connected with the processes of manufacturing soda during the lapse of nine years since that period, and giving also some details of the increase which has taken place in the extent of this important manufacture during that time. One of the most important events has been the passing of "The Alkali Act, 1863," rendering it imperative that manufacturers decomposing common salt for the production of sulphate of soda, should condense not less than 95 per cent. of the hydrochloric acid gas evolved by such decomposition. In the former paper, the means the author had devised and carried into successful operation in the year 1836, for effecting such condensation, were described, these means being now adopted universally, and so successfully that, in many instances, this condensation exceeds 99 per cent. The most important use for the hydrochloric acid obtained by such condensation is the manufacture of hypochlorite of lime, or bleaching powder, the demand for which has taken an extraordinary development since the introduction of straw, Esparto grass, and some other substances than rags for the manufacture of paper. At the date of the previous paper, the chlorine was obtained by the action of hydrochloric acid on peroxide of manganese. Recently Mr. Walter Weldon, of London, has perfected a process by which peroxide of manganese is obtained from the chloride of manganese prodnced by the action of hydrochloric acid on peroxide of manganese; and this process has been successfully carried into practice in this district, also in that of Newcastle, and it has already been adopted by some of the largest manufacturers in both localities. Allusion was then made to Mr. Deacon's very scientific process for the manufacture of chlorine without the use of manganese. Mr. James Hargreaves, of Widnes, has also devised means for producing chlorine without the use of oxide of manganese. The iron slag is treated with hydrochloric acid, and thereby protochloride of iron in solution is obtained as a by-product, which is evaporated, producing dry protochloride; and this, by slow application of heat with access of atmospheric air, becomes perchloride, which undergoes decomposition, yielding chlorine and peroxide of iron. In the former paper it was remarked that nearly all the sulphur used in this manufacture, the cost of which is about equal to two fifths of the total cost of materials required, was reobtained in combination with calcium, forming what is expressively designated as "alkali-waste;" and it was noticed, also, that this presented a problem worthy of attention for its solution. Mr. L. Mond has made a near approximation to the solution of this problem. His process consists in causing atmospheric air to be brought into intimate contact with the alkali-waste as this is left in the lixiviating vats after

treatment with water. A very pure sulphur, almost absolutely free from arsenic, is obtained by this mode of working, which has been carried out successfully by various manufacturers; but the quantity of sulphur obtained is far short of that contained in the waste, and the author considered the problem still remained as an exercise for ingenuity and perseverance. The former mode of obtaining copper and silver from the burnt residua of coppery pyrites which had been used for yielding sulphur to manufacture sulphuric acid, has been superseded by a process devised by Mr. Henderson, which consists in mixing a small proportion of salt with burnt pyrites, previously ground to a fine powder, exposing this mixture to a low red heat, and passing through it a current of air. By these means the small portion of sulphur which has escaped being consumed in the burnt pyrites becomes oxidized, producing sulphate of iron, which decomposes common salt, yielding chloride of copper and sulphate of soda, which are obtained in solution on lixiviating the product with water. The copper is then precipitated from the solution by means of iron, and is obtained in the metallic state. A large quantity of oxide of iron is obtained as a residuum from the lixiviation. This is sold to the iron-smelters for the production of iron. These operations are carried out very extensively by the Tharsis Metal Company at Glasgow, Newcastle, and Widnes; and at the Widnes Metal Company, Mr. J. A. Phillips has carried out successfully a process invented by Mr. Claudet, of London, for extracting gold, silver, and lead from the burnt residua of coppery pyrites. In the year 1861, during the negotiation of the French Treaty of Commerce, it was estimated that the total quantity of salt decomposed in Great Britain for the production of soda was 260,000 tons per annum. Of this quantity 125,000 tons were decomposed in what is called the Newcastle district, and 135,000 tons in the Lancashire district. According to the returns of the Alkali-Manufacturers' Association for the year 1869, the total quantity of salt decomposed for the manufacture of soda was 326,000 tons, thus showing an increase of 66,000 tons, or 25 per cent. on the total. Of this quantity the decomposition in the Newcastle district in 1869 was 142,000 tons, which, being compared with 125,000 tons in 1861, shows an increase of 17,000 tons, or 13·6 per cent. The decomposition in the Lancashire district is returned as 184,000 in 1869, against 135,000 tons in 1861, showing an increase of 49,000 tons, or 36 per cent. Thus the Lancashire district in 1869 exceeds by 30 per cent. the total quantity decomposed in the Newcastle district during the same year. One of the most important applications of soda to other manufactures is that of the production of soap. In the year 1852, when the excise duty was finally abolished, the total production in Great Britain was equal to 1600 tons per week, less than one half of which was produced in the Lancashire district. The present production in the Lancashire district is fully equal to the total production in 1852. Regarding the immense number of manufactories at work in Lancashire for the production of chemical substances to be used in bleaching, dyeing, calico-printing, &c., the conclusion was arrived at that Lancashire is the largest seat of chemical manufactures in this country.

On a Method for the Determination of Sulphur in Coal-gas. *By* A. Vernon Harcourt, *F.R.S.*

This paper gave a description of a piece of apparatus, which was exhibited in action, and an account of the results obtained with it. The apparatus consisted of a small Bunsen burner, whose nozzle passed into a glass cylinder, closed at both ends, through which air was drawn by an aspirator. The products of combustion were washed with an ammoniacal solution of copper during their passage through a system of bulbs. A Woulfe's bottle, filled with fragments of pumice steeped in ammoniacal solution of copper, served to purify the air at its entrance, and also to charge it with ammonia.

The apparatus had been tested by passing through it carbonic acid mixed with a known amount of sulphurous acid, and also by washing a second time the gases leaving it. Satisfactory results had been obtained. Moreover two or more analyses of the same sample of gas gave numbers which were closely concordant.

On the Separation from Iron-Furnace Cinder of Phosphoric Acid for Manurial Purposes. By James Hargreaves.

On Artificial Stone and various kinds of Silica. By the Rev. H. Highton, *M.A.*

Silica is found in various forms, more or less insoluble. Some kinds can only be united with alkalies in the heat of a glass-furnace; other kinds can be dissolved under a high pressure, and after a considerable lapse of time, by solutions of alkalies; other forms, again, to which the author particularly wished to call attention, can be dissolved under proper precautions even in the cold. Natural silica of this kind was exhibited both from Germany and England.

By means of this soluble silica, artificial stone can be formed harder than any natural stones, except the very hard granites and primitive rocks. The process is as follows:—A concrete is made with any good hydraulic cement. When this is dry, it is steeped in an alkaline solution of silica, in which is placed a quantity of free silica. The following chemical process then takes place. The lime in the concrete extracts the silica from the solution, leaving the alkali free, which immediately attacks the free silica and conveys it in its turn to the concrete. This process goes on continually till the lime in the concrete is saturated with silica.

By this process, within a week the strength of the concrete is increased from 50 to 150 per cent.; and by a longer continuation of the process the strength is still more increased.

The following is the comparative resistance to a crushing-force of several kinds of stone:—

	lbs.
The silicated concrete, or patent Victoria stone, per square inch ..	6441
Aberdeen granite	7770
Dartmoor granite	6993
Peterhead granite	6216
Yorkshire landing	5851
Stafford blue brick	4032
Portland stone	2426
Bath stone	1244

The stone formed in this manner has been tried as a pavement in the busiest part of Cheapside, and in many other parts of London, and for steps, lintels, sills, &c., in many parts both of this kingdom and abroad, as well as in India.

The whole of the stone in the new warehouses, 27 St. Mary Axe, is made in this manner.

As a cheap strong stone, when manufactured on a large scale, it is likely to supersede natural stone, except where the latter is very cheap and abundant.

In localities, as on the Thames, where there are facilities for obtaining good hydraulic cement and hard broken stone, it can be manufactured at a much lower cost than Yorkshire or other stone can be procured.

On the Time needed for the completion of Chemical Changes. By Dr. Hurter.

On the Prevention of Lead-poisoning in Water. By A. Gordon.

Various substitutes for lead piping have been tried, but all are more or less open to objection. The substitute recommended by the author was that invented by Mr. Haines, C.E. It consists of a leaden pipe with an internal pipe of block tin, both having been previously pressed together so as to form a homogeneous whole. By this process the piping retained all the flexibility of lead, while the inner tube of tin was strong and thick enough to prevent any access of water to the exterior leaden pipe.

On the Estimation of Sulphur in Coal-gas. By W. Marriott.

On the Typical Hydrocarbons, from Marsh-gas to Anthracene, with the Oxidation of the latter into Anthroquinone and Alazarine. By Dr. MAC-VICAR.

On Atmospheric Ozone. By T. MOFFATT, *M.D., F.R.A.S., F.G.S.*

The results in this paper were deduced from observations extending over a period of twenty years. The author stated that the maximum of ozone occurred with the conditions of the equatorial current of the atmosphere, and the minimum with those of the polar current. The quantity of ozone is greater in the night than in the day. It varies with the seasons. With thunderstorms, the aurora, the zodiacal light, hail, snow, and sleet, it is above or below the mean quantity, according to the readings of the barometer. If the readings be increasing, ozone is in minimum quantity; but if they be decreasing, it is in maximum quantity, with these phenomena. The author does not consider that the electrolytic action of the sunbeam upon water and vegetable essences produces ozone; it is, however, he states, produced by the action of the sun's rays upon turpentine. He believes phosphorescence to be the chief source of atmospheric ozone; and from results deduced from a long series of observations on the phosphorescence of the sea in connexion with ozone, he finds that the maximum of the latter takes place when the sea is phosphorescent, and the minimum when it is not phosphorescent. From observations taken during four passages over the North Atlantic, it would appear, the author states, that the minimum of phosphorescence of the sea and of ozone occur in the "ice-track" and in the proximity of icebergs.

On the Quantity of Phosphoric Acid excreted from the System in connexion with Atmospheric Conditions. By T. MOFFATT, *M.D., F.R.A.S., F.G.S.*

The author mentions that in a paper of his on the above subject, read at the Meeting of the British Association last year, he gave the results of observations for each month. These results showed that the maximum quantity of phosphoric acid is excreted under the conditions of the equatorial current of the atmosphere, and that the minimum takes place with those of the polar current. Observations continued during the winter months of last year afford similar results, from which the author concludes that the quantity of phosphoric acid formed in the system by the oxidation of the phosphorus in the protein and phosphorated fat of the blood in the peripheral system, and in the lungs, is determined by the pressure of the atmosphere, just as phosphorus is oxidated out of the system.

On a New Theory respecting the Heating of Liquids. By J. BIRKBECK NEVINS, *M.D.*

On Artificial Alizarine, with Illustrations. By W. H. PERKINS, *F.R.S., F.C.S.*

Note on Claudet's Process for the Extraction of Silver. By J. ARTHUR PHILLIPS.

It has long been known to those engaged in copper-extraction by the wet process that the precipitate produced not only contains a notable quantity of silver, but also traces of gold. No attempt, however, to separate the precious metals, and to turn them to profitable account, had been made up to the commencement of the present year, when Mr. F. Claudet patented a process for the separation of silver from ordinary copper-liquors by the addition of a soluble iodide.

The amount of silver present in burnt ore seldom exceeds 18 dwts. per ton; and as the whole of this is never obtained in solution, it follows that, in order to obtain satisfactory commercial results, the process employed should be both cheap and expeditious.

The vats in which the burnt ores which have been roasted with salts are lixiviated, generally receive some eight or nine successive washings, either with water or with water acidulated by hydrochloric acid; and of these the first three only contain a sufficient amount of silver to be worth working.

For the purpose of removing the soluble salts, hot water is employed; and as a large proportion of the chloride of sodium used remains undecomposed, it acts as a solvent for the chloride of silver produced during the process of furnacing.

The several operations for the extraction of silver are conducted in the following manner; and as the first three washings contain 95 per cent. of the total amount of that metal dissolved, these alone are treated.

These liquors are first run into suitable wooden cisterns, each of the capacity of about 2700 gallons, where they are allowed to settle. The yield of silver per gallon is now ascertained by taking a measured quantity, to which are added hydrochloric acid, iodide of potassium, and a solution of acetate of lead. The precipitate thus obtained is thrown upon a filter, and, after being dried, is fused with a flux consisting of a mixture of carbonate of soda, borax, and lampblack. The resulting argentiferous lead is passed to the cupel; and from the weight of the button of silver obtained the amount of that metal in a gallon of the liquor is estimated.

The liquor from the settling-vat is now allowed to flow into another, whilst at the same time the exact amount of a soluble iodide necessary to precipitate the silver present is run into it from a graduated tank, together with a quantity of water equal to about one tenth of the volume of the copper-liquor. During the filling of the second tank its contents are constantly stirred; and when filled, a little lime-water is added, and it is allowed to settle during forty-eight hours.

The supernatant liquors are, after being assayed, run off, and the tank again filled, whilst the precipitate collected at the bottom is, about once a fortnight, washed into a vessel prepared for its reception.

This precipitate is chiefly composed of sulphate of lead, iodide of silver, and salts of copper, from which the latter are readily removed by washing with dilute hydrochloric acid. Thus freed from salts of copper, the precipitate is decomposed by metallic zinc, which reduces the iodide of silver completely, and, to a certain extent, also the sulphate of lead. The result of this decomposition is:—

1st. Iodide of zinc, which, after being standardized, is employed in subsequent operations to precipitate further quantities of silver.

2nd. A precipitate rich in silver, and also containing a valuable amount of gold.

The results of six months' experience of this process at the Widnes Metal-works show that $\frac{1}{2}$ an ounce of silver and $1\frac{1}{2}$ grain of gold may be extracted from each ton of ore worked, at a total cost, including labour, loss of iodide, &c., of 8*d.* per ton, or 1*s.* 4*d.* per oz. of silver produced. If from this be deducted 6*d.*, the value of the 3 grains of gold in each ounce of silver, the cost of production, per oz. of silver, will be 10*d.*, and the expense of working a ton of ore 5*d.*

On the Absorption of Hydrogen by Electro-deposited Iron. *By* W. Chandler Roberts, *Chemist of the Mint.*

The author reminded the Section of a paper read during the Meeting of the British Association at Exeter, by Dr. Jacobi of St. Petersburg, on the electro-deposition of iron, specimens of which were submitted for inspection.

The well-known experiments of Mr. Graham proved that palladium occluded 900 times its volume of hydrogen; and Dr. Jacobi considered that the electro-deposition of iron was attended by a similar absorption of hydrogen, although to a less degree.

By submitting this idea to the test of experiment, the author found that the iron contained at least 15·5 times its volume of hydrogen. The experiments were effected by heating the iron *in vacuo*.

Similar results were also obtained by Lenz and Klein.

Mr. Graham also proved that tubes of malleable iron, when heated to redness, allowed hydrogen to penetrate their walls. The experiments were then attended by unavoidable errors; but by employing a tube of iron electro-deposited on a rod of wax, Mr. Roberts was enabled to confirm the results obtained by Mr. Graham.

On Vanadium, illustrated by Preparations of its Compounds. *By* Prof. H. E. Roscoe, *F.R.S.*

On the Chemical Composition of Cotton. *By* E. Schunck, *Ph.D., F.R.S.*

It is generally supposed that cotton, when quite pure, consists entirely of woody fibre or cellulose, and that its composition is consequently represented by the formula C_{12}, H_{10}, O_{10}. It is certain, however, that in the raw state, as furnished by commerce, it contains a number of other ingredients, some of which occur so constantly that they must be considered essential constituents of cotton, viewed as a vegetable product. The object of the bleaching process, to which most cotton fabrics are subjected, is to deprive the fibre of these other ingredients, and leave the cellulose behind in a state of purity. Notwithstanding the importance of an accurate knowledge of every thing relating to cotton from an industrial point of view, the substances contained in it along with cellulose have never been subjected to a special chemical examination, and, consequently, very little is known about them. The object which the author had in view in undertaking his investigation was to endeavour to throw a little more light on the nature of these substances. All foreign and extraneous matter introduced during the process of manufacture was left entirely out of consideration. The author further confined his attention to those constituents of the fibre which are insoluble in water, but soluble in alkaline lye, and are consequently precipitated by acid from the alkaline solution.

The material employed by the author was cotton yarn, which he preferred to unspun cotton for several reasons, the principal being that yarn is comparatively free from mechanical impurities (such as fragments of seed-vessels, &c.), while, on the other hand, if proper care be taken, no impurity is added during the process of spinning to those previously existing. The yarn was boiled in an ordinary bleacher's keir for several hours, with a dilute solution of soda-ash. The resulting dark-brown liquor, after the yarn had been taken out, drained, and slightly washed, was removed from the keir into appropriate vessels, and mixed with an excess of sulphuric acid, which produced a copious light-brown flocculent precipitate, while the liquid became colourless. This precipitate was allowed to settle, the liquid was poured off; and after being washed with cold water to remove the sulphate of soda and excess of acid, it was put on calico strainers and allowed to drain. A thick pulp was thus obtained, which, when dried, assumed the appearance of a brown, brittle, horn-like substance translucent at the edges. In one experiment 450 lbs. of yarn, made from East-Indian cotton, of the variety called "Dhollerah," yielded 0·33 per cent. of the dried precipitate. In another experiment, made with 500 lbs. of yarn spun from American cotton, of the kind called in commerce "middling Orleans," 0·48 per cent. was obtained. The total loss sustained by yarn during the bleaching process amounts to about 5 per cent. of its weight. Only a small portion, therefore, of the matter lost is recovered by precipitation of the alkaline extract with acid. This precipitate formed more especially the subject of the author's investigation. It was found to consist almost entirely of organic substances; and of these the following were distinctly recognized:—

1. A species of vegetable wax, to which the name of "cotton wax" may be given.
2. A fatty acid, identical with margaric acid.
3. and 4. Brown resinous colouring-matters.
5. Pectic acid.
6. A trace of albuminous matter.

The author described the method employed by him for separating these substances from one another, and obtaining them in a state of purity; and he then gave an account of their properties and composition.

On the Phenomena of the Crystallization of a Double Salt. *By* J. Berger Spence.

On an Attempt to determine the Boiling-point of the Saturated Solutions of various Salts by boiling with Steam of 100° *C.* *By* Peter Spence, *F.C.S.*

The author stated that he had been engaged in a series of experiments with the view of determining the boiling-points of the saturated solutions of various salts, by blowing into these solutions steam of 100° C., and taking the highest point of temperature attainable by this means as the boiling-point of the saturated solution of the salt operated upon. This was following out into practical results the discovery brought by the author before the Exeter Meeting, that steam of 100° C. gives much higher temperatures than its own in such solutions. Several difficulties were alluded to; but these the author hoped to overcome, and concluded by giving a list of solutions that he believed are determined with an approach to accuracy.

	° C.	° F.		° C.	° F.
Nitrate of potash . . .	113·6	236·5	Chloride of manganese .	121·6	251
Sulphate of ammonium .	108·6	227·3	Acetate of barium . .	103·3	218
Nitrate of soda . . .	118·8	246·2	Chlorate of barium . .	100·1	223
Chloride of ammonium .	114·1	237·5	Binoxalate of potash . .	105	221
Chloride of sodium . .	109·4	229	Carbolic acid	117·2	229
Chromate of potash . .	106·6	224	Chromic acid	128·3	263
Chloride of barium . .	105·0	221	Nitrate of silver . . .	119·4	247
Sulphate of copper . .	105·2	221·5	Phosphate of soda . .	104·7	220·5
Sulphate of magnesia .	105·5	222	Sulphate of zinc . . .	104·7	220·5
Carbonate of potash . .	129·4	265	Nitrate of baryta . . .	102·2	216
Sulphate of soda . . .	104·4	220	Nitrate of strontia . .	107·7	226
Chlorate of potash . .	105·5	222	Tungstate of soda . . .	107·7	226
Sulphate of potash . .	102·7	217	Ferrocyanide of potassium	104·4	220
Oxalic acid	111·9	233·5	Chloride of zinc . . .	172·2	342
Sulphate of alumina .	105	221	Iodide of potassium . .	115·5	240
Nitrate of lead . . .	104·7	220·5	Sulphate of nickel . .	111·6	228
Bichloride of mercury .	100·5	213	Carbazotic acid . . .	103·3	218
Chloride of potassium .	109·4	229			

On the Discrimination of Fibres in Mixed Fabrics. *By* J. Spiller, *F.C.S.*

In the course of an experimental inquiry undertaken for the purpose of identifying the fibres entering into the composition of mixed fabrics, the author was led to the discovery of the fact that silk alone, of all the materials ordinarily used in the production of textile fabrics, is soluble in concentrated hydrochloric acid. The chemical properties of the silk solution so prepared were described, and a photographic application pointed out by the author, who exhibited in this connexion a matt-paper print, which was stated to have been produced in a much shorter time than that commonly required for an ordinary print on a plain salted paper. A hydrochloric-acid solution of silk was used, which, being made as concentrated as possible, and neutralized by addition of ammonia, furnished a new organic chloride, particularly suitable for salting paper intended for solar camera enlargements. For the purpose of identifying wool in the presence of cotton, flax, jute, &c., it is recommended to immerse the fabric or loosened fibres in a warm aqueous solution of picric acid, which dyes the wool of a bright yellow without imparting any colour to cotton. Thus, by treating a mixed fabric successively with hydrochloric and picric acids, valuable indications are afforded regarding its constitution.

On Marbles from the Island of Tyree.
By Edward C. C. Stanford, *F.C.S.*

The author exhibited some polished specimens of two kinds of marble from the Island of Tyree, in Argyleshire. One of these is unknown elsewhere. It is a beautiful pink marble with dark green spots, which are crystals of hornblende. The pink colour is due to peroxide of iron, which is scarcely soluble in dilute hydrochloric acid. The other is a white compact magnesian limestone, containing suffi-

cient silica to render it very hard and durable. The amount of silica varies in different specimens. The following analyses show the composition:—

	Pink.	White.
Calcium carbonate	70·85	50·70
Calcium sulphate	trace	
Magnesium carbonate	2·35	37·92
Peroxide of iron	3·40	
Calcium phosphate	....	0·80
Silica	....	10·18
Hornblende	23·40	
Water	....	0·40
	100·00	100·00

The proportion of hornblende in the pink marble is variable.

On the Retention of Organic Nitrogen by Charcoal. *By* EDWARD C. C. STANFORD, *F.C.S.*

This paper was a continuation of one read by the author at the Exeter Meeting last year, entitled "A Chemical Method of treating the Excreta of Towns." In this paper the value of the dry as opposed to the water-closet system was warmly advocated. It was shown that the only two real disadvantages alleged against the application of the dry system to large towns were:—

1st. The large quantity of valueless material required to be carted in and out; and

2nd. The difficulty of obtaining the necessary supply.

These two difficulties are at once removed by the process proposed by the author. Instead of earth, X-charcoal, or charcoal derived from the carbonized excreta, is used as the deodorizer; of this, in proportion to earth, only one-fourth of the quantity is required, while the substance removed affords by reburning the necessary supply. The daily increase of this is available for manure. So far, therefore, from being applicable only to small towns, the system must pay best where the population is the densest. The nitrogen, phosphoric acid, and potash are all retained; and the expense of removal in proportion to that by water carriage is infinitesmal.

Houses properly constructed are only visited once a-year, and the removal is less in amount, and even less disagreeable, than that of the house ashes. All the malaria and other evils of connexion with sewers are avoided, and health is ensured. Twelve months' experience on a large scale are stated to have fully demonstrated all the advantages claimed for this process, and proved it an efficient solution of the sewage difficulty. As, however, some chemists have assumed that the action of charcoal on animal nitrogenous matter is to oxidize it into nitrates, this was made the subject of a special investigation. The author showed in his former paper that excreta being already an oxidized product, there was little foundation for this assumption as far as regards this animal matter. Now he also shows that even meat when dry is unaffected by either X-charcoal or seaweed charcoal. Mixtures of these charcoals with meat and with solid and fluid excreta were allowed to become dry, and then tested monthly for nitrogen for six months. It was found that there was no loss of nitrogen, no oxidation, and no formation of nitrates. As this result is contrary to the usual view, further experiments with other charcoals are promised.

Dust as a Ferment. *By* CHARLES R. C. TICHBORNE, *F.C.S., M.R.I.A.*

The author's paper was an attempt to deal with the chemical activity of dusts as actual ferments. He referred to his researches in 1866 (the cholera year), in which he demonstrated that the organic portion of street dusts in large towns consisted of stable manure finely ground. Such dust generally gives an acid reaction, but there were some cases taken from the locality of cab-stands which presented traces of ammonia. The following is one of the specimens given:—

Dust from Grafton Street, Dublin (dried at 100° C.).

Inorganic matter	68·9
Organic matter	31·1
	100·0

Such dusts act as active ferments.

Analyses of dusts taken from the principal public buildings in Dublin are given in the paper, of which the subjoined is a synopsis:—

	Inorganic matter.	Organic matter.
Top seats in Merrion Hall (the largest place of public worship)	67·9	32·1
Gallery of the Theatre Royal	46·8	53·2
Ancient Concerts-room (ventilating space above the gas)	64·3	35·7
Nelson's Pillar (monument 134 feet high)	70·3	29·7

The large amount of iron in some of these dusts is peculiar; for instance, that obtained from the "Ancient Concerts-room" gave 21 per cent. as the amount of peroxide in the inorganic matter. This probably proceeds from a slow combustion of the gas-burners.

Some further experiments were then instituted to determine how far, and to what extent, these dusts would operate as ferments, and a volumetric system of measuring the intensity of any process of fermentation was contrived. The process is based upon the reduction of a nitrate of any base to a nitrite in the presence of substances undergoing putrefactive fermentation. In these experiments precautionary measures were adopted, so that all the fermentations induced were proper to the dusts used as ferments. A mixture of cane- and milk-sugar was the pabulum used in conjunction with mineral substances, including a weighed portion of nitrate of potassium. These experiments, conducted in flasks closed with cotton-wool, were kept at a temperature of 20° to 28° C. They were examined from day to day in the following manner:—5 cubic centimetres of the clear liquid were withdrawn with a graduated pipette, and the level of the remaining liquid marked upon the flask, so that it could be made up to the original level if there is any loss from evaporation. The 5 cubic centimetres were then mixed with a little mucilage of starch and iodide of potassium. On acidulating with sulphuric acid, blue iodide of starch is at once formed in each case, representing the $N_2 O_3$ present, or the nitrate reduced. A volumetric solution of hyposulphite of sodium was then used for the estimation of iodide of starch found. It is rather a curious observation that, if the nitrate of potassium did not exceed $\frac{1}{4}$ of a grain to the ounce of fermenting liquid after the first 24 hours, all traces of nitrites disappear, although there is still nitrate present. The results are different if we introduce 2 to 3 grains. It is probable that, in the reduction of the nitrates preparatory to the assimilation of the nitrogen, a nitrate is the first stage; but that if the ferment bears a considerable proportion to the nitrate present, the nitrogen will be assimilated in the form of some lower compound of nitrogen. One point of importance is evident, that, in the examination of potable waters, if nitrates are present, but if no nitrites, it is no proof that decomposition is not actually proceeding at the time as regards the organic matter therein.

The different results are then given in detail as regards the dust examined, and which were introduced as ferments. They conclusively proved the powers of these dusts for this purpose; they also seem to point to a curious phase of the subject, viz. that dust taken at a great height, as from "Nelson's Pillar," seems to have as great or greater activity than that which would be obtained from a building which is nightly crowded to suffocation. This may in some measure be due to the extreme levity of the spores. There is probably an altitude of the maximum of activity for all localities as regards dust

On the Action of Low Temperatures on Supersaturated Saline Solutions.
By C. TOMLINSON, *F.R.S.*

It is known that when a saline solution, saturated at a certain temperature, is reduced in temperature, salt is deposited; but in the case of certain salts their supersaturated solutions, contained in clean vessels, and protected from the action of nuclei, do not by reduction of temperature deposit the normal salt, but a salt of a modified character, and of a lower degree of hydration, as in the case of sodic sulphate, when a seven-watered salt is formed instead of the usual ten-atom hydrate. Mr. Tomlinson, in some recent experiments, has shown that the supersaturated solutions of certain salts may be reduced to near the temperature of zero without any deposit of salt; but below this they form tetrahedral crystals, which increase until the whole of the solution becomes solid. If, now, the tube be put into snow and water at 32°, the solid melts rapidly, and the solution becomes clear, bright, and supersaturated as before. This effect may be produced any number of times, provided the solution be preserved from the action of nuclei, or carriers of nuclei, such as the air. The only precautions to this end are to use clean filtered solutions in clean tubes, kept plugged with cotton-wool.

A supersaturated solution of the double salt, formed by the sulphates of zinc and magnesia in atomic proportions, became solid at −10° F., that of the double sulphate of copper and magnesia at −4°, that of sulphate of zinc and potash alum at 0°, that of sulphate of zinc and ammonia at 4°. Other examples are given in the paper, with cases in which modified salts are formed and remain permanent when the temperature is raised.

If the cotton-wool be removed only for a few seconds, while the solution is solid, it crystallizes during the melting into the normal salt, thus showing the action of a nucleus.

At these low temperatures the water of the solutions does not separate and freeze, but combines with the saline molecules so as to form unstable hydrates. It is remarkable that in so many cases the crystalline form of these hydrates should be tetrahedral.

On a Salt invisible in its Mother Liquor. *By* C. TOMLINSON, *F.R.S.*

Sir David Brewster has pointed out a method of examining precious stones in the rough, for the purpose of determining their refractive density and freedom from flaws without the trouble and expense of grinding and polishing them. For this purpose the rough stone is put into a mixture of oil of cassia and olive-oil, so adjusted as to be of about the same refractive density as the stone, when the latter becomes invisible, or nearly so, while the flaws and defects start into view.

When a supersaturated solution of the double salt formed by mixing the sulphates of zinc and soda in atomic proportions with a small quantity of water, boiling and filtering into clean tubes, is exposed to the temperature of about 0° F., a salt is formed, and is permanent for some days at ordinary temperatures, but it is invisible on account of its having the same index of refraction as its mother liquor. The latter is now only a saturated solution. On closing the tube with the thumb, and inverting it so as to allow the mother liquor to drain off, air enters into the cavities in the crystals; and on allowing the mother liquor to flow back, these air-filled cavities, having a different refractive index, become visible, and have a massive appearance.

On the Electro-deposition of Copper and Brass.
By W. H. WALENN, *F.C.S.*

The present condition of the electro-deposition of copper and brass is put forward in this paper with sufficient reference to the history of the subject to enable comparatively recent improvements to be well understood, but treating the process in a practical manner, and with reference to some improvements and manipulations that are adopted by the author.

Ordinarily, a solution containing the cyanides of copper and zinc, respectively dissolved in a "solvent solution," consisting of a mixture of potassic cyanide with

a salt of ammonium, is employed to deposit brass. This solution, however, evolves hydrogen copiously, and is only workable by means of two Grove's cells. The author finds that the evolution of gas may be either totally stopped or much lessened by dissolving as much of the metallic cyanides as the solution will take up, and then further charging the solution with the copper and zinc oxides. The evolution of gas may be totally stopped by the further addition of cupric ammonide, which may possibly carry the combined oxygen to the cathode, according to the following equation:—

At the cathode before chemical reaction.		*At the cathode after chemical reaction.*
$\{Cu_2O, 4NH_3 + 4H_2O\} + H_2$	$=$	$Cu_2 + 4NH_3 + 5H_2O$,
Cupric ammonide. Hydrogen.		Copper. Ammonia. Water.

Malaguti and Sarzeau's formula for cupric ammonide being used,—that is to say, before decomposition or chemical reaction takes place, the whole of the cupric ammonide, together with the eliminated hydrogen, goes to the cathode; after the decomposition or chemical reaction has taken place, metallic copper is deposited, ammonia is in solution, and water is formed.

In treating the ordinary cyanide copper solution for the prevention of the evolution of hydrogen, the zinc cyanides or oxides, mentioned in the instance of the brass solution, are left out.

When the evolution of hydrogen has been stopped, a single Smee's cell is sufficient to deposit the alloy; but, in practice, a single Grove's cell, or equivalent magneto-electric power, is employed, in order to shorten the time of immersion in the electro-coating bath.

The author prefers to use potassic cyanides and neutral ammonium tartrate, when mixed with water, to form the solvent solution for either brass or copper. The quality of brass (yellow or red) depends upon the heat of the solution.

Acid solutions, in general, give a spreading or matted deposit, alkaline solutions a bristling one. The contact of the coating is promoted by working the solution hot. The article should be pickled, scrubbed with sand, washed, scrubbed with a portion of the depositing solution, and then placed in the depositing trough. After deposition, the article is washed and dried in hot mahogany sawdust. Complete protection from rust, and a satisfactory coating for any purpose, is given by the use of the acid-depositing bath subsequent to that of the alkaline bath.

Specimens of electro-deposited brass, by the author's processes, were exhibited.

On the Weldon Process for the Manufacture of Chlorine. *By* WALTER WELDON, *F.C.S.*

Communication respecting a Resolution of the Committee of Section B *on the proposed establishment of a New School of Applied Science by Government.* *By* Professor A. W. WILLIAMSON, *F.R.S.*

Professor Williamson communicated to the Section a Resolution which had been passed in identical terms by the Committees of three Sections, viz. those of Physics, Mechanics, and Chemistry. It was to the following effect:—

"That in the opinion of this Committee it is inexpedient that new institutions for the teaching of science, pure or applied, such as the proposed Engineering College for India, should be established by Government, until the Royal Commission, now holding an inquiry into the relation of the State to scientific instruction, shall have issued their report.

"That the Council of the British Association be requested to consider this opinion, and, should they see fit, to urge it upon the attention of Her Majesty's Government."

It is well known that there are in the Universities and Colleges of the United Kingdom complete and systematic courses of instruction in the various branches of science required for engineering pursuits, and that young men do obtain through them the needful scientific preparation for professional work in engineering. There

are also special courses of instruction in engineering subjects given by men of the greatest eminence.

In matters relating to the higher education, Government have taken action from time to time, by establishing special schools, without first taking means to ascertain what arrangements already existed for carrying out the object in view, or what kind of arrangement had been proved by experience to be most effectual for the purpose.

Under these circumstances, the British Association urged upon Her Majesty's Government last session the desirability of appointing a Royal Commission for the purpose of obtaining information respecting the existing arrangements for scientific instruction in this country; and it is well known that a Commission has already begun to take evidence on the subject.

There is reason to believe that the labours of the Commission will be of great value to the cause of scientific education, and will prepare the way for the development of some system worthy of England, by showing what are the available resources of the country for such a purpose, and what has been found by experience to be the respective merits of the various methods in use.

Under these circumstances, it was with no small surprise that an announcement was received to the effect that Government is about to establish an official engineering college.

GEOLOGY.

On Newly discovered Species of Elephants.* *By* Dr. Leith Adams.

Notes of a recent Visit to the Great Tunnel through the Alps, and of several points of Geological interest suggested by the condition of the Works in their present nearly complete state. *By* D. T. Ansted, *M.A.*, *F.R.S.*, *For. Sec. G.S.*

The author, referring to memoirs recently pnblished by Professors Sismonda and M. Elie de Beaumont on the rocks met with during the construction of the tunnel, directed attention to the fact that the tunnel will perforate the crest of the main chain of the Alps at a point nearly midway between Mont Tabor and the Mont Cenis, and directly under Mont Frejus, the height of the crest between these limits varying from 7000 to 10,400 feet above the sea. The valleys on the two sides of the crest being of very different levels, the determinatiou of the site for the tunnel involved many difficulties, but was suggested by an Italian in 1841. The works were commenced in 1857, and on the 31st of July there remained less than 2000 feet out of 40,000 to pierce.

The rocks of the crest of the Savoy Alps are metamorphic schists alternating with bands of quartzite, gypsum, and highly calcareous schist with masses of anthracite. They are the middle and lower divisions of the mesozoic period, ranging perhaps from the Jurassic to the Triassic periods. Near Moutiers they contain characteristic fossils, chiefly liassic species.

The level of the valley of the Arc at Modena, near which town the tunnel works commence, is more than 200 feet below the point on the hillside where the tunnel enters. This latter point is 3946½ feet above the sea. On the Italian side the tunnel emerges near Bardonneche 4381½ feet above the sea, or 435 feet higher. The bearing of the tunnel is N. 14° W.–S. 14° E. The strike of the rocks perforated is nearly uniform, and is N.E.–S.W., the rocks having a mean dip of about 50° N.W. Being thus cut obliquely, the real thickness of rock is about three-fifths the distance bored. The total length of the tunnel being about 40,000 feet, the thickness of rock traversed is about 24,000 feet. There is no indication of fault in any part.

* A communication ordered to be printed *in extenso* among the Reports.

Specimens of the rocks traversed are preserved. On the French side the work began by 420 feet of tunnelling through disintegrated and decomposed rock, representing an actual thickness of about 200 feet of weathered material. After this there was 6000 feet of tunnelling (3600 feet of rock) through talcose and steatitic schists, with carbonate of lime and magnesia, containing hyaline quartz and crystals of calcite and dolomite. Among the rocks was a conglomerate, and at the bottom coarse micaceous gritstone. Beyond these was 800 feet (actual thickness) of very hard quartzite, and then 1800 feet of gypsum, crystalline limestone, and talcose schist. All these belong to the upper and middle divisions of the anthracitiferous rocks of the Alps, ranging from the Oxford clay to the lower oolites, both inclusive. All the rest of the tunnel is through a vast series of schistose limestone and calcareous schists, often steatitic, at least 18,000 feet in actual thickness, representing the Lias, the Rhætic rocks, and perhaps some Triassic rocks. Throughout these are many instances of slickensides, and a few crystals of iron-pyrites and galena.

The author pointed out that the effect of pressure on these rocks was inappreciable, except that they exhibited numerous small folds. There are very few crevices and fissures; these were almost all partly filled with crystals.

Observations on temperature were made, but not very systematically, at distances of about 500 metres, by bore-holes put in laterally to a distance of about three metres. At 6200 metres (20,342 feet), at a depth of more than 5000 feet, the thermometer showed 27° C. This would show a rate of increment of one degree Fahrenheit in upwards of 100 feet. This is confirmed by other observations on the temperature of the rock, and also of the water met with in the various fissures.

The quantity of water yielded during the tunnelling has been exceptionally small. Except on two or three occasions, where small water-containing fissures were tapped and water came off under pressure for a few hours, the general quantity has hardly varied, and does not exceed 4 litres per second (say, 100,000 gallons per day). The water contained oxide of iron and sulphates of lime and magnesia.

On the Matrix of the Gold in the Scottish Gold-fields. *By* JAMES BRYCE, *M.A., LL.D., F.G.S.*

Up to July of last year, the source of the gold of the alluvial workings in Sutherland had not been determined. Many of the miners had been at other diggings, where the gold occurred in quartz reefs, and accordingly their search was constantly directed to the discovery of such reefs, but without success. Sir R. I. Murchison, Rev. J. M. Joass, Mr. John F. Campbell, and Mr. Cameron, in their several papers, had all offered surmises on this point; but no definite information had been made public. The author had directed his attention to the elucidation of this point; he had not succeeded in detecting any quartz reef, but he had found the gold in its native seat in another rock. The banks of the Suisgill burn consisted of alternating coarse whitish granite and a highly crystalline mica-slate. On crushing the granite and washing the sand, grains of gold were found in every specimen. A similar result was obtained by crushing and washing specimens of the mica-slate, but the gold was less abundant, and was absent from several specimens.

A structure very similar existed in the Kildonan burn, whose alluvia also yielded gold; but the granite here was not tested by him. He would not be understood to affirm that granite was the only seat of the gold; on the contrary, he thought it highly probable that it was diffused through all the metamorphic rocks of the district, as Sir R. I. Murchison had supposed. He did not think it necessary to call in the aid of old ice-action, as Mr. J. F. Campbell had done; the existing drainage might be credited with the whole of the gold. The specimens of granite were selected by himself, and washed for him by one of the men engaged in the diggings.

Early in the last winter gold-grains were found in considerable quantity in the alluvia of the Errick and Nairn rivers towards their mouths, and were soon after detected at various points far up the channels of these streams. The author had examined the upper valleys of the Errick and Nairn, and found them to consist of a great body of granite invading metamorphic slates. He was accompanied

by Mr. W. M. M'Gillivray, of Inverness, who had had much experience in gold-washing; and on handing over to him for examination certain specimens of granite very similar to that of the Suisgill burn, Mr. M'Gillivray found in them several grains of gold. Further inquiry was needed, in order to ascertain whether the gold existed here in remunerative quantity.

On the History and Affinities of the British Coniferæ.
By William Carruthers, *F.L.S., F.G.S.*

Having pointed out the great divisions of this natural order, the author traced the appearance and development of its numbers in the stratified rocks. The *Araucarieæ*, of which there were fifteen living species, natives of the southern hemisphere, made their appearance in the coal-measures, eight species having been determined from the structure of the wood. In the secondary rocks cones belonging to six species had been detected, all of them having close affinities with the section *Entacta* of *Araucaria*. The *Pineæ*, a large group living in the northern hemisphere, first appeared in Devonian strata, were contained in the coal, and greatly increased in number in the secondary rocks. The *Taxodieæ*, having fifteen species, living chiefly near the shores of the North Pacific, appeared in the Stonesfield slate, and were continued by species of *Sequoia* through the Cretaceous and Eocene periods. The *Cupresseæ* are known only from tertiary strata by fruits and foliage. The *Taxineæ*, containing nearly 100 living species, have been determined in the Carboniferous rocks from a fruit; several fruits occur also in the Sheppy beds of Eocene age.

On the Sporangia of Ferns from the Coal-measures.
By William Carruthers, *F.L.S., F.G.S.*

The author had detected in calcareous nodules from the beds of coal at Bradford several sporangia of Ferns belonging to the same species, and all characterized by the presence of the elastic ring which is found in the *Polypodiaceæ*. The ring is oblique and continuous round the sporangium, and these peculiarities, together with the shortness of the pedicel, induced the author to refer them to a Hymenophyllaceous genus. Some of the sporangia were filled with the roundish spores.

Remarks on the Fossils from the Railway Section at Huyton.
By William Carruthers, *F.L.S., F.G.S.*

The great value of this collection, made by the Rev. H. Higgins, depended as much upon the comparatively limited number of species met with as on the fine state of preservation in which they occurred. It was possible to arrive at considerable (in some cases absolute) certainty as to the different parts of the same species. Of the four species of *Calamites*, the materials existed in the specimens from Huyton for reconstructing the entire plant of at least one. The roots, long considered to be a distinct plant under the name *Pinnularia*, were present in great abundance. The species had a delicate fistular stem of the type described by Professor Williamson at a previous meeting of the Section, but of great size. The scars of the fallen branches were shown in several specimens as well as the foliage, which was preserved in the early bud condition, as well as in its fully developed state. Several fruits were found showing the structure of the cone, described by the author under the name of *Volkmannia Binneyi*, but with differences that were at least of specific value. A cone having the structure of that described by Professor Williamson probably belonged to *Calamites longifolius*, with the foliage of which it was associated in these beds. Specimens of *Sphenophyllum* were exhibited and referred to *Calamites*. The light thrown on the structure of *Lepidodendron* by the specimens was then dwelt on, and especially two undescribed cones—one long and slender, with a single sporangium on each scale, the other short, and having two sporangia on each scale. The stem and foliage of *Flabellaria* (a palm-like Lycopodiaceous genus) occurred among the fossils, as well as several species of beautifully preserved ferns. Two specimens of insect remains

had also been found—the one by Messrs. Clementshaw and Smith, young gentlemen whose interest in natural science was due to the revival of those studies in our great schools, and whose personal efforts had largely contributed to its advancement at Rugby.

Note on an Antholithes discovered by C. W. Peach. *By* William Carruthers, *F.L.S., F.G.S.*

Mr. Peach had discovered near Falkirk a fine series of Antholithes, which he had submitted to the author. Several of them exhibited the fruits still attached, and thus established the true nature of these fossils, which had been hitherto considered so anomalous. The fruits had been described by authors as species of *Cardiocarpum.*

On the Glacial Phenomena in the Central District of England. *By the* Rev. H. W. Crosskey, *F.G.S.*

On the Formation of Boulder-clays and Alternations of Level of Land and Water. *By the* Rev. J. Gunn, *M.A., F.G.S.*

The author observed that the boulder-clays have been regarded as indications of a glacial epoch, whereas at the time of their deposit the land must have subsided at least 500 feet beneath the present sea-level, and the greater extent of sea would tend to raise the temperature, except so far as it would be lowered by the influx of icebergs. That, in consequence of such depression, the perpetual snow-line would be altered to the same amount, and an enormous quantity of ice would be gradually disengaged and set floating from Greenland, for instance, by marine currents in a southerly direction; icebergs would be the result, boulders would be dropped, and the boulder-clay formed without the intervention of any glacial epoch. That by the contrary process of the elevation of the land glaciers and other descriptions of ice would be formed, and what is called a glacial epoch would ensue.

The effect of such alternate oscillations of level might be shown to be, in the southern hemisphere, to cover the plains and leave the mountains in the form of islands standing out above the sea, as exemplified in the Pacific; and in the northern to produce the contrary result, as now exemplified in this country. The author supported these changes on palæontographical evidence; and while attributing them to oscillations of the level of land and water, expressed his inability to ascertain the causes of such oscillations, and left the solution of their origin to mathematicians and astronomers.

On the Glacial and Postglacial Deposits in the Neighbourhood of Llandudno. *By* Hugh F. Hall, *F.G.S.*

In the paper the author described a general section of the beds exposed at the following places:—Gogarth, west side of the Little Orme, east side of the Little Orme, Dyganwy, Rhos, Colwyn, and Llandulas.

The base bed taken was the mountain limestone. Above this there is exposed at the Little Orme a bed 3 to 5 feet thick of mountain-limestone rubble, produced probably by the action of frost during the earlier part of the glacial period breaking the exposed rock into fragments. This again is covered by a bed, which in its greatest development (at Llandulas) is 150 feet thick, of *Boulder-clay,* which he regarded as the result of the grinding down of the subjacent strata by land-ice, which probably at this period came down to the waters' edge—in fact, *the true glacial period.* He showed that this bed is invariably composed of the materials which would result from the grinding down of the rocks in the immediate neighbourhood, being at Rhos a very stiff bluish-grey clay, very full of small pebbles, principally slate, all ice-scratched, with large blocks of mountain limestone, greenstone, and volcanic grits, showing ice-grooves and smoothing. At Gogarth, again, it varies in colour from dark brown to grey, very gritty and sandy, full of scratched pebbles, and many chert fragments. At Dyganwy it is a low cliff of black clay,

evidently derived from the grinding down of the slate. This is the best section for the observation of ice-markings. In a hollow in this clay at the Orme there is a deposit of 20 feet of stratified grey clay, evidently a denudation bed from the boulder-clay, showing, where opened by weathering, distinct ripple- and rain-marks. A contemporaneous bed, the evidence of a shore condition during the depression of the boulder-clay, of 20 feet of irregular and false-bedded sands and gravels lies also above the boulder-clay. At the Little Orme this bed is hardened by carbonate of lime into a conglomerate, to be seen in the cliff and in enormous fallen masses on the shore.

The subsidence of the land still continuing the shore condition ceases, and a continuous bed, common everywhere, of *red clay*, some 20 feet thick, overlies the lower sands and gravels. Then an elevation seems to have taken place, and another series of sands and gravels, upwards of 50 feet in thickness, shows another shore condition, best seen in the ballast-pit at Colwyn. Lastly, the thin bed of blue-black clay, without pebbles, is exposed in the Dyganwy section, the result of a second denudation of the boulder-clay, after both the sands and gravels and the red clay had been carried away. This being the sequence of the beds, the author called attention to the following points:—

1st. That *colour* is no criterion for deciding as to the F glacial bed, which at Gogarth is dark brown and grey; at Dyganwy, almost black; Little Orme, dark grey; Rhos, a lighter grey; Colwyn shore, blue; and Llandulas, red-brown: in fact the colour depends upon the materials of which the rocks *in the vicinity* are composed.

2nd. That the materials of which this clay is composed are always those found in the immediate neighbourhood, and even the large boulders can generally be traced to no great distance. Thus the Gogarth clay is evidently the result of the grinding down of the mica-schists and limestones of Anglesey, and probably of the millstone-grit, which is now entirely denuded from the district. The clay east and west of the Little Orme and at Rhos shows the result of the passage of the ice over the mountain limestone and Silurian beds, the latter supplying the adhesive material which makes this clay so much stiffer. At Dyganwy the black clay is from the underlying slates, and at Llandulas the reddish-brown is due to the wearing of the Old Red Sandstone, which is still found inland, and many boulders of which are seen on the shore.

3rd. The author conceived this clay to be the result of the pressure and passage of land-ice, disintegrating the whole surface of the country which it capped; and he would confine the term *boulder-clay* to this one bed, believing it to be the only *true glacial clay.*

4th. This bed is invariably denuded, rising in bosses all along the shore, and having the superposed beds lying unconformably upon it.

5th. The red clay (D), which is invariable in colour and constituents, showed an undoubted change of conditions in the land during the period of its deposition, being, as he conceived, the result of extensive denudation in more northern regions, spread over the sea-bottom by currents, the scratched pebbles and boulders being due to melting or stranded icebergs.

The author argued that with such different constituents for these beds it is time to adopt some more definite names than the general one of boulder-clay, which is commonly applied to the *series.* He referred to the sections on the eastern coast as confirmatory of his views, as illustrated by his personal observations in Holderness, where as clearly distinct a series of beds occurs.

General Section of Drift in the Neighbourhood of Llandudno.

A.	Sand dunes.	
B.	Blue-black clay, without pebbles	1 ft.
C.	Sands and gravels, about	50 ft.
D.	Red clay, greatest development	20 ft.
E.	Sands and gravels, greatest development..	20 ft.
E^2.	Stratified grey clay	20 ft.
F.	Boulder-clay, greatest development	150 ft.
G.	Mountain-limestone rubble	5 ft.
H.	Bedded mountain limestone.	

On the Green Slates and Porphyries of the Lake-district. *By* Prof. Harkness, *F.R.S.*, and H. A. Nicholson, *D.Sc.*, *F.G.S.*

The authors described the sequence of the rocks which in the Lake-country are known as green slates and porphyries, as being made up of traps at the base, of a middle series consisting of ashes, traps, amygdaloids, and trappean breccias, and of an upper series consisting of hornstone porphyry.

The former is very persistent over the Lake-district, while the latter is by no means so uniform in its occurrence. The middle series varies much in mineral character according to locality. The neighbourhood of Keswick and in Borrowdale exhibits this series in its most typical form. West and north-west from Keswick the ash-beds are less abundant, their place being occupied by a porphyry with large crystals of felspar; and in the northern slopes of the Culcleckfells this porphyry is the sole representative of the middle portion of the group. At Carrickfell this porphyry is in contact with syenite; and here its character has become greatly modified, it appearing as a diorite: and at Roughtengill it has also undergone changes from the influence of granite veins; for here it occurs as a hypersthene rock.

The green slates and porphyries of the Lake-country represent the Upper Llandeilo and a portion of the Caradoc rocks; and their average thickness does not seem to be more than 5000 feet.

On Some Thermal Springs in the Fens of Cambridgeshire. *By* F. W. Harmer, *F.G.S.*

In several farm-yard wells near Chatteris in Cambridgeshire, of the depth of from 10 to 14 feet, the author had found on the 14th of March, 1870, water of the temperature of from $66\frac{1}{2}°$ to $74\frac{1}{2}°$ Fahr., that of the air being then but 37° in the shade, and the water in Vermuden's drain (one of the main arteries of the fen-drainage, which is within 100 yards of one of the wells) having at the same time but 39° of heat, and being covered with thin ice.

At a subsequent visit to one of the localities on June 2nd, the temperature of the air being in the shade 70°, and of the water in the neighbouring drains $71\frac{1}{2}°$, the well showed $79\frac{3}{4}°$ of heat.

An analysis of the water had been made by Mr. Francis Sutton, F.C.S., of Norwich, but he had been unable to discover any reason for supposing that the heat was generated locally by chemical causes.

The fen-district being below the sea-level, the ground is permanently saturated with water at a short distance from the surface, and as this water at the slight depth of 10 feet seems constantly to maintain, summer and winter, such an abnormal temperature, its agricultural effects cannot be inconsiderable.

The author hoped that an endeavour would be made by local geologists to ascertain whether these thermal springs extended beyond the area of about 10 to 15 square miles in which he had observed them, and also to determine in what way and by how much the agriculture of the district was affected by them.

Mr. Judd, F.G.S., of the Ordnance Survey, had informed the author that the secondary strata which underlie the alluvial deposits of the fens are in the adjoining counties considerably faulted and dislocated; but whether in this way the water described may be in communication with the central heat of the earth, or whether the matter is to be explained by chemical causes, he does not at present offer a decided opinion.

On the Extension of the Coal-fields beneath the newer Formations of England, and the successive Stratigraphical Changes to which the Carboniferous Rocks have been subjected. *By* Prof. Edward Hull, *M.A.*, *F.R.S.*, *F.G.S.*

The author commenced by referring to the paper which Sir R. I. Murchison had laid before the British Association at Nottingham, "On the Parts of England and Wales in which Coal may, or may not, be looked for," and expressed his gratification that his own views, arrived at by a somewhat different process of reasoning, coincided in the main with those of his respected chief. Especially was this the

case as regarded the absence of coal in the eastern and portions of the midland counties, now overspread by Mesozoic formations. The author proceeded to show that there was evidence that the coal-measures were originally deposited in two continuous sheets, one to the north and the other to the south of a ridge of old land, formed of Silurian rocks, which stretched eastward from Shropshire, and ranged along the south of the Dudley coal-field. This dividing ridge, or barrier, had probably never been altogether submerged beneath the waters in which the coal-measures were deposited. Referring to the tract of coal-measures which lay to the north of the central barrier, it was shown that towards the north the boundaries of the coal-formation were formed by the Cambro-Silurian rocks of North Wales, the Lake-district, and portions of the "southern uplands" of Scotland. The southern limits were formed by the barrier of old land, and over this intervening area the coal-measures were spread in one continuous sheet, and attained their greatest vertical dimensions towards the north-west. To the south of the barrier, the strata were deposited in the greatest thickness towards the west or south-west.

At the close of the coal-period, disturbances of strata (resulting probably from lateral pressure acting from the north and south) took place over the whole Carboniferous area of the north of England, whereby the strata were thrown into a series of folds, the axes of which ranged along approximately east and west lines. These disturbances were accompanied and followed by enormous denudations, by which the coal-measures were swept away over large tracts of the north of England, and the northern limits of the Lancashire and Yorkshire coal-fields were approximately determined.

Referring to the tract south of the central barrier, Professor Hull expressed his opinion that the east and west flexures, being parallel to those of the north of England, were referable to the same geological period, namely, post-Carboniferous (or pre-Permian). At this period the northern and southern limits of the South Wales coal-field, the axis of the Mendip Hills, and the easterly trend of the culm-measures of Devonshire were determined. Denudation of strata on an enormous scale accompanied these movements. After the deposition of the Permian beds over the inclined and denuded edges of the Carboniferous rocks, disturbances accompanied by extensive denudation took place along lines nearly at right angles to those of the preceding period; that is, along north and south lines approximately. To this epoch, the axis of the Pennine chain and all north and south trendings of the strata were to be referred. Some of the results brought about by these movements were the disseverance of the Lancashire and Cheshire from the Yorkshire and Derbyshire coal-fields, the determination of the western limits of the Flintshire and Derbyshire coal-fields, the disseverance of the Forest of Dean coal-field from that of South Wales, and the uptilting of the Lower Carboniferous rocks along the eastern margin of the Somersetshire coal-field, beneath the Jurassic formations. From these considerations it seemed clear to the author that the basin-shaped form of nearly all the coal-fields (the basins being sometimes partially concealed by the Mesozoic rocks) was due to the denudations acting over areas of elevation intersecting each other nearly at right angles, and corresponding to two distinct epochs—the pre-Permian and pre-Triassic. Professor Hull then proceeded to show that over these Carboniferous basins the Permian and Triassic rocks were distributed according to a well-defined plan of south-easterly attenuation, or thinning away towards the south-east; and he concluded by discussing the views of Sir R. I. Murchison, Professor Ramsay, and Mr. Godwin-Austen, regarding the existence or absence of coal under the Cretaceous or Tertiary strata of the south of England.

On the Red and Coralline Crags. By CHARLES JECKS.

The author suggested the following reasons, as rendering it probable that the Red and Coralline are quite as nearly connected with each other as the Red and Norwich Crags. If the palæontological difference between the Red and Norwich Crags be about 20 per cent., and yet be considered synonymous, how is it that the Coralline Crag, which only contains 10 per cent. fewer recent species than the Red,

should be held as distinct from it? When we find that 103 shells are common to the Red and Coralline Crags which are not found in the Norwich Crag, whilst only two are common to the Red and Norwich Crags, and are not found in the Coralline, surely such a fact directly implies not only a connexion, but one almost as close between the Coralline and Red as the Red and Norwich Crags. There seems, indeed, every reason to believe that the transition from the Coralline to the Red Crag was gradual; if there were now to be an elevation of sea-bottom, including what we call the Coralline and Laminarian zones, the former would naturally become Laminarian, while the latter would become a Littoral zone, and this in all probability without any really sudden change in species, but by a slow process of elevation; nay, is there any sudden change now observable in the species inhabiting these zones? do they not gradually commingle? and if this be so as regards the Coralline and Laminarian zones of the present time, is it not quite as likely to have been so with regard to the Coralline and Red Crags?

Sir C. Lyell, in his sixth edition of the 'Elements,' seems distinctly to favour the idea of the unity of the Crag, in the following extract:—"The shells of the Crag exhibit clear evidence of a gradual refrigeration of climate, which went on in the area of England from the time of the older to that of the most modern Pliocene strata."

With regard to the objection, that the denudation of the Coralline, as evinced by the unconformability of deposition of certain parts of the Red Crag, shows a certain break, as it were, in the continuity of the deposit, would it not be obviated, in some measure at least, by the fact of there having been many changes in the conditions of life in the Coralline Crag species owing perhaps to the intrusion of other species and consequent disturbance in their mutual relations, so that in course of time they would die out, together with a gradual, long continued, but decided change in climatal conditions? Upon the whole, then, it seems probable that the period from the commencement to the end of the Pliocene is one of gradual transition, of which the Coralline, Red, and Norwich Crags represent so many stages, not distinct and separate, but more or less connected together by various changes in the relations of one organism to another, caused by variation of species under natural selection, and also by changes in climatal conditions and nature of sea-bottom.

Remarks on Newer Tertiary Fossils in Sicily and Calabria. *By* J. Gwyn Jeffreys, *F.R.S.*

During the last deep-sea exploring expedition in H.M.S. 'Porcupine,' in the Bay of Biscay and along the Atlantic coasts of Spain and Portugal, Mr. Jeffreys procured at considerable depths, and especially from 994 fathoms, many species of Mollusca in a living or recent state, some of which had been previously regarded as fossil only, and extinct, and all of them belonging to the newer tertiaries of Sicily and Calabria; and he believed that a record of the fact might lead to the discovery of the geological phenomena which had caused the fossilization of such species in that limited area. Several of these species inhabit northern and even arctic seas; and among them are *Terebratula cranium*, *T. septata*, *Pecten aratus*, *P. vitreus*, *Lima excavata*, *Mytilus vitreus*, *Leda frigida*, *Limopsis aurita*, *L. borealis*, *Dentalium abyssorum*, *Puncturella noachina*, *Hela tenella*, and *Pleurotoma carinata*. Other species now found in a living or recent state are *Terebratula sphenoïdea*, *Tellina compressa*, *Verticordia acutecostata*, *V. granulata* (the last two being Japanese), two species of *Fissurisepta*, *Trochus suturalis*, *Turbo filosus*, *Omphalus monocingulatus*, *Scalaria pumila*, *Cyclostoma delicatum* of Philippi (*Reclusia*?), and *Pleurotoma hispidula*. One of the species in the second list or category (*Fissurisepta papillosa*) had been also dredged by Mr. Jeffreys last autumn at Dröbak, in Norway; and he was of opinion that our knowledge of the arctic marine invertebrate fauna was very imperfect. The newer Tertiary fossils of Sicily and Calabria had been to a great extent investigated by Dr. Philippi formerly of Cassel, Prof. Seguenza of Messina, the Abbé Brugnone of Palermo, and Dr. Tiberi of Resina near Naples; and their collections had been examined by Mr. Jeffreys. Two suggestions or questions were submitted by the author of the present paper,

viz.:—1st. Have not all the deep-sea species of European Mollusca originated in the north, and spread southwards in consequence of the great arctic current? 2nd. Inasmuch as the Pliocene division of the Tertiary formation is now ascertained to contain scarcely any extinct species, and future explorations may reduce the percentage of such species to *nil*, may not that artificial division hereafter merge in the quaternary formation, and the Tertiaries be restricted to Eocene, Miocene, and Oligocene?

On the Age of the Wealden.

By JOHN W. JUDD, *F.G.S., of the Geological Survey of England and Wales.*

Unconformities between formations indicate, as Mr. Darwin, Prof. Ramsay, and other geologists have argued, the lapse of enormous periods of time. Between the Oolitic system, terminating with the Portlandian, and the true Cretaceous, commencing with the Gault, there is not only an immense physical break, but *a total change in species.* The researches of continental geologists have shown that, intercalated between these two systems, there exists two others, each in every way worthy to rank with them, the Tithonian and the Neocomian; these do not, however, *entirely* bridge over the interval, for the Cretaceous is almost everywhere unconformable to the Neocomian.

The English Wealden consists of a mass of freshwater strata, probably not less than 2000 feet thick. Forming its lower and upper members, however, are certain fluviomarine strata, which form passages into the marine beds below and above the Wealden. The lowest of these fluviomarine or passage series is the well-known Purbeck formation, the marine beds of which contain Oolitic fossils. In the Isle of Purbeck, the Isle of Wight, and elsewhere is found another series of strata, less known, but not less important, which indicates the gradual passage upward of the Wealden into the Upper Neocomian (Lower Greensand).

Of especial interest, from the large fauna which it yields, is the marine band of Punfield, to which the attention of geologists was first directed by Mr. Godwin-Austen in the year 1850. This bed is only 21 inches thick, and is situated 140 feet below the top of the Wealden; the author has found that it contains a series of fossils (including many species and one genus quite new to this country) identical with those of the coal-bearing strata of Middle Neocomian age in Eastern Spain, which are more than 1600 feet thick.

The Wealden presents every appearance of being a single continuous formation. In its lower portion it contains marine beds with oolitic fossils, and graduates into the Portlandian; in its upper part it contains other marine beds with Middle Neocomian fossils, and graduates into the Upper Neocomian. We are thus led to the conclusion that the great epoch of the Wealden commenced towards the close of the Oolitic period, that it continued through the whole of the Tithonian and the Lower and Middle Neocomian, and only came to an end at the beginning of the Upper Neocomian.

In confirmation of these views as to the age of the Wealden, there exists much palæontological evidence. Still further support is afforded to them by the manner in which Wealden and Neocomian beds are found alternating with one another in France, especially in the Pays de Bray and in the district of Champagne.

Professor Huxley has indicated the necessity of establishing a distinct classification for freshwater and terrestrial formations, the breaks between which do not correspond with those of the marine series. Of this necessity the Wealden, representing, like the "Poikilitic," several very distinct marine formations, is a very striking illustration.

The author has before shown that the deposition of the Wealden strata of Northern Germany commenced at the close of the Oolitic period, and had terminated before the end of the Lower Neocomian. He concludes therefore that the English and German Wealdens are not strictly contemporaneous, and that, the areas being quite disconnected, they are probably the products of two different rivers.

On some Points in the Geology of Strath, Isle of Skye. *By* Professors KING *and* ROWNEY.

The authors entered into a minute description of a section of the east shore of Loch Slappin. The rocks consist of syenite, overlaid by serpentinous marble or ophite, and a number of unaltered stratified deposits following in consecutive order. An unbroken passage was traced from the marble to the highest beds; the latter are more or less charged with Liassic fossils. The following conclusions were come to by the authors:—(1) That the ophite of Strath is an altered rock of the Liassic period, as long ago maintained by Macculloch and Geikie; (2) that it possesses the same microscopic features as those, supposed by some to be of organic origin, which occur in a corresponding rock of earlier geological ages, known in Canada, Connemarra, and elsewhere; (3) that igneous action, developing a granitic rock, and producing decided metamorphism in an adjacent deposit, has operated at a later geological period in Skye than in any other part of the British islands. Referring to their published memoirs in the 'Quart. Journ. Geol. Soc.' vol. xxii. 1866, and the 'Proc. Roy. Irish Acad.' vol. x. 1870, in which certain of the above microscopic features in the Skye ophite were first made known, the authors in the present paper announced their discovery of some others, which completely identify this comparatively modern rock with the "eozoonal" marble of Canada, belonging to the Laurentian system; and they maintained that the repeated occurrence, so often pointed out by them, of "chamber casts" (grains of serpentine, &c.), "canal system" (metaxite, &c.), and "nummuline layer" (chrysotile), in *metamorphic or crystalline rocks only*, proves in the simplest manner the purely mineral origin of the so-called "*Eozoon Canadense*." Sections and numerous specimens, including a large block of the Skye "eozoonal" marble, were exhibited.

On the Discovery of Upper Silurian Rocks in Roxburgh and Dumfriesshire. *By* CHARLES LAPWORTH.

On the Tertiary Coal-field of Southern Chile. *By* G. A. LEBOUR, *F.G.S. &c., and* W. MUNDLE, *M.E.*

The coal-formation of Chile occupies a marginal position along the western coast of South America, extending from Talcahuano near Concession on the north, to the Straits of Magellan on the south. It rests unconformably upon mica-schists and other metamorphic rocks, which form the main geological feature of the country.

The coals are for the most part of an inferior description, mere lignites in fact. The accompanying rocks are alternating sandstones (grey, white, and yellow), shales and indurated clays, true underclays, and occasional bands of calcareous matter. A detailed typical section of the strata at Coronel was given by the authors.

The fossils of these beds belong, some of them, to what in Europe would be undoubted secondary age; for various reasons, which he will defer to another paper, Mr. G. A. Lebour believes with Darwin that they indicate more probably a very early *Tertiary* age.

The other portions of the paper referring to the mode of deposition &c. of the beds in question cannot be written in short without the aid of figures.

On the Stratigraphical Distribution of the British Fossil Gasteropoda. *By* J. L. LOBLEY, *F.G.S.*

On the Silurian Formations of the Centre of Belgium. *By* Professor CONSTANTINE MALAISE (*of Gembloux*).

M. Malaise pointed out that the *terrain ardoisier* of D'Omalius d'Halloy (the Ardennais and Rhénan formations of Dumont) are the representatives of the Cambrian, Silurian, and Devonian rocks of England. He has attempted to establish the analogues in Belgium, where at first the references to English types were incorrect.

The Belgian formations regarded as Silurian and Cambrian are found in the Ardennes in Brabant, parallel to the Meuse and Sambre, and near Dour in Hainault.

The Silurian or Cambrian of the Ardennes rests unconformably on the Devonian. The ill-preserved fossils that have been found do not sufficiently determine the age, consisting only at present of *Dictyonema* and part of a Trilobite belonging to the genus *Paradoxides*, which would place it in the Cambrian. The true Belgian Silurians] belong to part of the *Rhénan* series of Dumont, in which Silurian fossils were found in 1860 by M. Gosselet.

The Brabant Silurian deposits extend over an area about 70 miles long, the greatest width being 16 miles. That of the Sambre and the Meuse is a strip about 40 miles long, and less than two miles wide.

The Brabant series is divided into four groups, the upper alone of which has yielded fossils, and this alone is represented in the Sambre and Meuse district. The following are the groups in descending order:—

1. Gembloux series (quartziferous schists).
2. Oisquezcq series (variegated and graphitic schists).
3. Tubise series (quartzites).
4. Blaumont (lower quartzites).

From the upper series 52 species have been obtained, several of which appear new; they include Trilobites, Brachiopoda, and Graptolites, characteristic of the upper members of the Lower Silurian, a second stage of M. Barrande, mixed with some Upper Silurian species.

Synchronism and Foreign Equivalents.—With regard to the analogies of the Belgian Silurians with those of other countries, the author agrees with M. Barrande that his second stage, represented in the Bohemian district by quartzite, and also represented in almost all Silurian districts, occurs in its ordinary state in Belgium. In England it includes the Llandeilo and overlying Caradoc groups, and in Ireland the recognized equivalents, while in France, Spain, Portugal, Thuringia, Sweden, Norway, Russia, and North America it is known by various names. It is represented in Belgium by the genera *Illænus, Trinucleus, Ampyx*, and others.

Species have also been found referred to *Dalmanites, Cheirurus, Lichas, Calymenes, Acidaspis, Homalonotus*, but to groups peculiar to the second stage. The great development of *Orthis* common in England, Russia, and the United States is also remarkable in Belgium. *Cystidea* have also been met with.

On the Formation of Swallow-holes or Pits with Vertical Sides in Mountain Limestone.* *By* L. C. Miall.

The paper described two kinds of these cavities, one designated "cavities of erosion," and the other "cavities of subsidence." A detailed account was given of a singular excavation at the head of Swaledale, typical of the first species. Its peculiarities were defined as consisting of vertical, fluted sides, and isolated pillars in the centre of the pits. Falling water, aided by pebbles, was looked upon as the source of excavation, and a thick surface-covering of drift, retentive of moisture, was regarded as an essential feature, the spongy mass discharging the rainfall at certain regular points. Those swallow-holes were next considered whose existence is due to subsidence of an undermined crust; and many examples were cited and discussed, principally from the mountain-limestone district of Craven. The effects of such subsidences upon superficial deposits (as of glacial drift) were adverted to in conclusion.

On the Evidences of Recent Changes of Level on the Mediterranean Coast†. *By* George Maw, *F.G.S., F.L.S., &c.*

The author in this paper pointed out, from personal observation, the various evidences the Mediterranean coast presents of changes of level, both above and below the existing shore-line.

* This paper is printed at length in the 'Geological Magazine' for November 1870.
† Printed *in extenso* in the 'Geological Magazine' for December 1870.

Evidences of Depression.

(1) The general absence of cliffs, indicating that the sea had not been sufficiently long at its existing level to excavate a high escarpment, implying a comparatively recent change, probably of depression.

(2) The current setting in from the Atlantic. The author contended that evaporation could scarcely compensate for the great influx of water from the land-drainage of more than a third of Europe and a portion of Africa: this accession ought to produce an outflow through the straits. As the width of the straits bears so small a proportion to the area of the sea, the current setting in might be due to a general sinking of the bed now going on, and too slight to be perceptible on the margin of the area subject to the depression.

(3) The extension below the present sea-margin at Mentone of limestone-caverns and freshwater channels of subaërial origin.

Evidences of Upheaval.

(4) In a uniform rise of about 25 feet in distant parts of the Mediterranean of an older coast-line, exactly corresponding with the amount of emergence of the shell-bored columns of the Temple of Serapis. Mr. Gwyn Jeffreys had observed at Antibes a shell-bed containing recent Mediterranean species 25 feet above the existing water-line; and to the north of Gibraltar another similar bed existed, implying an ancient littoral zone 24 feet higher than the neighbouring shore. The Corsican marshes give evidence of a similar rise, the level flats being here and there covered by delta-like ridges of alluvial drift; these could only have been deposited by the streams which now flow at their base, when the marshes were submerged at least 20 or 25 feet.

(5) The coast-deposits of Posttertiary age at Gibraltar, Tangier, and Cadiz indicate various higher levels at which the Mediterranean has stood, ranging from 40 to 700 feet.

Some Remarks on the Denudation of the Oolites of the Bath District. *By* W. Stephen Mitchell, *F.G.S.*

On Geological Systems and Endemic Diseases. *By* Thomas Moffat, *M.D., F.G.S.*

The writer showed that the soil has an influence on the composition of the cereal plants grown upon it, and on the diseases to which the inhabitants are subject. The district in which he practises consists geologically of the Carboniferous and New Red Sandstone or Cheshire Sandstone systems. The inhabitants of the first are engaged in mining and agricultural occupations, those of the latter in agriculture. Anæmia, with goitre, is a very prevalent disease amongst those living on the Carboniferous system, whilst it is almost unknown among those living on the New Red Sandstone system; and consumption is also more prevalent amongst the inhabitants of the former. As anæmia is a condition in which there is a deficiency of the oxide of iron which the blood naturally contains, the author was led to make an examination of the relative composition of the wheat grown on the soil of Cheshire sandstone, Carboniferous limestone, Millstone-grit, and a transition-soil between Cheshire sandstone and the grit. The result of the analysis shows that the wheat grown on the soil of the Cheshire sandstone contains the largest quantity of ash, and that there is a larger quantity of phosphoric acid in it than in the soils of the Carboniferous and Millstone-grit systems; also a much larger quantity of oxide of iron than in either of them. He has calculated that each inhabitant on the Cheshire sandstone, if he consumes a pound of wheat daily, takes in nearly 5 grains per day of the sesquioxide of iron more than the inhabitant of the Carboniferous system, and who seems, therefore, to be subject to this great liability to anæmia in consequence of the deficiency of iron and phosphoric acid in the food he consumes. It is not only in the wheat grown upon the Carboniferous system that there is a deficiency in

the quantity of oxide of iron and the phosphates, says the author, but also in the blood of the animals reared upon it; so that the inhabitants upon that system take in a minimum quantity of these constituents of the blood, compared with that taken in by the inhabitants of the Cheshire sandstone. He stated that sheep were liable to anæmia—a fact which he attributed to sheep-walks being upon trap and limestone hills, in the soil of which there is but little, if any, iron.

On the Glaciated Condition of the Surface of the Triassic Sandstone around Liverpool. By G. H. Morton, *F.G.S.*

The most recent progress in local geology has resulted from the examination of the superficial or drift deposits which cover the country, and the discovery of the glaciated condition of the surface of the sandstone beneath. These superficial accumulations have been divided into Postglacial deposits (consisting of drift sand, bluish silt or mud, submarine forests) and Glacial deposits (including upper drift sand, boulder-clay, and lower drift sand). The latter subdivision is often absent; and, under these conditions, the Boulder-clay usually covers the surface. The author explained that this clay is the dark red clay so extensively used in the neighbourhood for the purpose of brick-making. It contains numerous pebbles and boulders, varying in size from that of a pea to immense blocks 6 feet in diameter, a large proportion of them being striated and ground flat on one or more surfaces by the action of the ice, similar to the specimens of boulders and pebbles brought from the glaciers of the Alps. In 1859 he described for the first time to the Literary and Philosophical Society of Liverpool the evidences of the action of ice on the sandstone in the neighbourhood. Having at that time only found such indications in a single locality, he attributed the striated surface to the grounding of an iceberg in the glacial sea. In 1866, having found several additional examples of this glaciation on both sides of the river, but at no great distance from it, he began to entertain the opinion that a glacier had descended the valley of the Mersey during the early part of the glacial period; and he made a communication to that effect to the Liverpool Geological Society. Lately, however, he had discovered similar evidences of ice-action at greater elevations, several miles from the river, and consequently had been compelled to adopt a new theory, namely, that a great sheet of ice once travelled over this part of the country from the south-east to the north-west. The first striated surface discovered was between Parkhill road and the Dingle, but had been destroyed by the erection of cottages over the place. This surface is 120 feet above the sea, and the strata belong to the pebble-beds of the Bunter formation. Two-thirds of a mile north the largest surface occurs in the waste ground on the north-east of North Hill Street. It is exposed at the present time, exhibiting several hundred square yards of ice-planed sandstone, closely covered with fine lines and grooves, all perfectly straight and parallel with each other, and running in the direction of 35° W. of N. The surface of the rock is 160 feet above the sea, and the strata belong to the pebble-beds of the Bunter formation. Striated rock has also been found at Kirkdale, at Wavertree, and Thatto Heath, all places on the Lancashire side of the Mersey; and at Oxton and Flagbrick Hill on the Cheshire side of the river. The author assumed the glaciation of the surface of the rock around Liverpool to have occurred before the submergence of the land at the beginning of the Glacial period, and was afterwards covered with Boulder-clay, which is partly the result of the waste of the land and partly the *débris* deposited by icebergs during the period of subsidence. The only alteration in the contour of the land seems to have been in the reduced elevation of the low ranges of the hills which traverse the district in the same direction as the ice seems to have done. It might appear a bold assertion to state that the country around Liverpool was once covered with a great ice-sheet, at a time when the land was some hundreds of feet higher than it is now; and that it afterwards subsided beneath the sea, when floating ice brought from the Lake-district and Scotland *débris* which became scattered over the ice-ground rocks in the form of Boulder-clay.

On the Mountain Limestone of Flintshire and part of Denbighshire. *By* G. H. MORTON, *F.G.S.*

The author pointed out that in Flintshire, within fifteen miles from Liverpool, there is a prominent ridge of Carboniferous or Mountain Limestone. It extends continuously from Prestatyn on the coast of Wales to Llandegla, a few miles north of Llangollen, the distance being twenty-one miles, and the strike of the limestone N. by S.E. and S. Instead of describing the formation generally, he had selected what appeared to be the four most favourable localities as centres of observation—Mold, Holywell, Newmarket (Flintshire), and Llangollen. He alluded to the country around or near these places, for neither Mold nor Holywell are actually upon the Mountain Limestone. Llangollen was included because of the grand section presented by the Eglwyseg rocks, about a mile from the town. The distance of the localities from each other is as follows:—From the Llangollen limestone district to that of Mold, eleven miles; from the Mold limestone to that of Holywell, six miles; and from the Holywell limestone to Newmarket, nine miles. The Eglwyseg rocks present a magnificent section of the Mountain Limestone, all the beds being exposed (except those at the base) at the western outcrop, in a ravine with precipitous cliffs on each side. The highest strata are at the top of the cliffs, half a mile to the west, at an elevation of 700 feet, the estimated thickness of the limestone being 1200 feet. The Millstone-grit of the Geological Survey succeeds the limestone, and is about 800 feet thick, coal being above it at Tyfynuchaf. One mile and a half to the west of the town of Mold there is a fine section of the Mountain Limestone. The vertical section of the strata at Newmarket is compiled from three horizontal sections, which each show the thickness of a subdivision. The upper, middle, and lower limestones are on the surface disconnected by faults, but the relative geological position of each is obvious. The lower grey and black limestones rest on Silurian strata, and are 750 feet thick at Moel Hiraddug. The middle or white limestone, 350 feet thick, is very different from any of the Hiraddug strata, as it is also from the upper black and grey limestones and shales, 300 feet thick, which crop out from under the overlying shales and sandstones of the Millstone-grit. In each of the four localities the Mountain Limestone admits of division into an upper, a middle, and a lower subdivision, each having distinct lithological and palæontological characters.

Appended to the paper was a list of 120 fossils found in the district described. An analysis of the list showed some interesting results. Excluding a few fish-teeth and scales and plants, all of which occur in the upper limestone, it appeared that the lower limestone does not contain any species peculiar to it, for some of them extend upwards into the white or middle limestone, whilst others pass up to the highest subdivisions. The earliest species, principally found at the base of Moel Hiraddug, are *Spirifera lineata* and *Syringopora reticulata*, and they continue upwards through the whole of the Mountain Limestone. These two species, with a *Lepidodendron* and another plant, seem to have been the first colonists that settled down in the Carboniferous sea of North Wales. The middle or white limestone presents 28 species which are peculiar to it (of course common species elsewhere); but of these, no less than 23 have only been found in the limestone ridge at Axton, Newmarket. This assemblage of species in such a limited area is extraordinary. In the upper limestone 23 species have been found to be peculiar to it; but they are all of rare occurrence, only single specimens having been found of about half of them. The common fossils have a considerable range, while those peculiar to certain subdivisions are mostly rare forms.

On some Future and Past Changes of the Earth's Climate. *By* R. A. PEACOCK, *C.E., Jersey.*

These important changes, he believes, are due (1) to rain and rivers, (2) denudations, (3) risings and sinkings of land, (4) the great range of temperature from $-58°$ F. in interplanetary space to $+150°$ and more on various parts of the earth's surface, even in temperate climates. These will account for a future warm and afterwards for a cold period, and for a glacial and a coal-period in the past.

Sir Charles Lyell gives the annual discharge of sediment by the Ganges and Brahmapootra as forty thousand millions of cubic feet, which are equal to a circle surrounding the earth's mean circumference two miles broad and one yard thick, in 105 years and 50 days. This enormous denudation will in no long geological period reduce the Himalayas down to the snow-line. All other mountains and land in the world (except deserts) are also being denuded, year by year, by means of rain and rivers, avalanches, glaciers, earthquakes, and alternate frost and thaw. For example, the river Pinder, an affluent of the Ganges, has a fall of 500 feet per mile for 11 miles; its water is all white foam, and has force enough to carry along large boulders, which, as well as the river's bed, become broken, comminuted, and abraded. For 16,000 feet in height of Mount Jawahir, there is a detritus of loose rocks and stones, evidently fallen from the upper part of the mountain. The like effects have been observed at the Matterhorn, in Tierra del Fuego, the Chilian Andes, Australia, Spitzbergen, and some small English mountains. In the Himalayas there are annual shocks of earthquakes, some of them severe, which loosen and bring down rocks. Avalanches bring down masses of stone, and glaciers convey along lines of stones called "moraines;" and alternate frost and thaw split and comminute rocks and stones. In these ways mountains are lowered, and in time there will be no mountain as high as the snow-line (unless risings by subterranean action occur again), and then a warmer period will be the consequence. And when the land is reduced to sea-level, the climate will be still warmer; because the air is chiefly warmed by heat transmitted and radiated from the earth, and land increases the cold by abstracting heat from the air in high latitudes and where the land is high, and augments the heat by radiation in low latitudes and where the ground is low; and water absorbs and retains solar heat *.

The latest glacial epoch seems to have been in the Recent, post-Pliocene, and Newer Pliocene periods. Older formations, as far back as the Permian inclusive, were warmer than at present, excepting some floating ice in the Cretaceous and Permian. A difficulty has been felt about the Miocene strata of the Superga Hill (Turin), how they became mixed up with erratics. It is now suggested that the hill and its strata, being of a conical form, must have been *uplifted*; and probably so in the Glacial period, whilst a glacier carrying the erratics rested upon it. The like may be true of the "flysch" conglomerate of Eocene date in the Alps. The largest part of Europe, the Sahara of Africa, and much of the basin of the St. Lawrence have been submarine since the early Eocene period †. And these submergences apparently assisted to bring on the Glacial period, because the sea above the submerged land would absorb and retain much solar heat; and the uplifting of the mountains, now to be stated, must have added much to the cold. Since the commencement of the Eocene period the Alps have acquired 4000 and, in some places, more than 10,000 feet of their present height; and the Pyrenees have attained their present height, which in Mont Perdu is 11,000 feet ‡. The Sierra Nevada, 11,000, and the Caucasus, 15,000 feet, had not then risen §. Prof. E. Forbes stated that Sorata (Andes), 24,812 feet high, contains Tertiary fossils to its summit. Mr. Darwin found chalk shells nearly 14,000 feet high in the Chilian Andes, and Capt. Strachey found Oolitic fossils 18,400 feet high in the Himalayas. All these mountains must have been upheaved since the *Coal-period*, and consequently we have no proof that there were *then* any mountains at all with summits as high as the snow-line; and they must have been higher than now, and consequently *colder*, by just as much as they have been denuded. But while lofty mountains have been eliminated as a source of cold in the Coal-period, it can also be proved that there was then probably *much more dry land* in the south to radiate heat, and produce a warm, equable, and humid climate which the Coal period requires. The annual quantity of solar heat thrown upon the earth during the geological period has probably been nearly uniform; but not so its effects on the earth's climate. Capt. Sturt found the sandy deserts of Australia so hot that they were almost a molten surface. On the other hand, if the site of Australia were now occupied even by comparatively shallow water, much

* Sir John Herschel, 'Outlines of Astronomy,' p. 236.

† Sir C. Lyell's 'Principles of Geology.' ‡ Ibid. § Ibid. Map, p. 251.

solar heat would be wholly lost. In the 'Porcupine' expedition seven surface-temperatures of the sea averaged only 58°·2 F., the extremes being 64° and 54°·8 *. Mr. Wallace shows, by his map of the Indian and Australian zoological provinces, that probably Celebes, New Guinea, Solomon Isles, and the intermediate islands were once united to Australia; and that Sumatra, Java, Borneo, and the Philippines were probably united to India. But, further, Mr. Darwin has shown that the Atolls and Barrier reefs of the Indian archipelago, and those of the Indian Ocean extending from North-west Australia to the north of Madagascar, as well as a very large tract of the Pacific archipelago (in the Torrid Zone), are all regions of *Gradual Depression*. It is therefore very probable that there were vast additional tracts of dry land on the south of Asia and in the Pacific, which would at once account for coal-plants and coal having been found as far north as 76°, as well as for the coal-plants and extinct mammals of Siberia, by reason of the extra heat radiated from the south and transmitted to the north.

But we are not bound to believe that these vast geological changes must necessarily date so far back as the Coal period. The uplifting of mountains took place since the early Tertiary, and the sinkings of land probably date within the same period, which was famous for upliftings and sinkings. If so, we can account for the fossil mammalia and reptiles of the Siwâlik Hills, for the fossil reptiles and leaves of plants found at Œningen, for the bones of monkeys found at the foot of the Pyrenees in France, for the tropical fossils of the Faluns of the Loire—all these fossils being subtropical or tropical, and due to the absence of lofty mountains and increased area of land in the south.

The future cold period will come on when the present land has been denuded to below high water, and will probably be aided by natural sinkings of land, and especially by the uplifting of mountains if such should recur. The present gradual (or intermittent) rise of northern Europe and Asia will assist to produce cold if it continues.

The Modern and Ancient Beaches of Portland.
By W. Pengelly, *F.R.S., F.G.S.*

The author commenced by stating that the *Modern* and *Ancient* Beaches of Portland, to which he purposed calling attention, were respectively the Chesil Bank, which connects the "island of Portland" with the mainland of Dorset, and the raised beach at Portland Bill; and that his object was to describe the pebbles which, during a recent careful search with Mr. W. Vicary, F.G.S., he had found in each of them. In both cases they were such as to show that during the era of the ancient beach, as well as at present, the direction in which materials were transported was *up-channel, i. e.* from *west to east*, and the prevalent winds were from the south-west. To account for the flints which occur on, at least, almost all the modern beaches of West Devon and Cornwall, he assumed the existence of submarine outliers of flint-gravel, similar to, and probably of the same age as, the supracretaceous accumulations which occur so abundantly in Devon, from the basin of the Teign eastward; and he mentioned several facts in proof of the occurrence of such outliers near the Start, the Dodman, and Lundy Island. In conclusion, he expressed the hope that ere long it might be part of the duty of the officers of the Geological Survey to map the bottom of the British seas and channels.

Notes on a Merionethshire Gold Quartz Crystal, and some Stream Gold recently found in the River Mawddach. By T. A. Readwin, *F.G.S.*

The author exhibited a quartz crystal which he picked from a large heap of quartz near Bala Lake, in 1863. At the time he said it was quite transparent, though tinged slightly with golden yellow, yet under the microscope the colour entirely disappeared. The crystal was put away in his cabinet, with other gold-

* Proc. Roy. Soc. No. 121, p. 465.

association of interest, and lay there unnoticed till last year. It had then become more opaque, and consequently of more interest to him. It has now all the appearance of a solid crystal of gold, and for which it has frequently been taken. The colour is pale, but he had observed that all gold found in quartz in that locality is light coloured, owing to the presence of a large percentage of silver, sometimes as much as 20 per cent.

He exhibited, also, some ounces of water-worn gold, some pieces weighing from 20 to 30 grains each, recently found in the Cain, a tributary of the River Mawddach, north of Dolgelly, and also a very rich specimen, broken from a quartz-lode at the Gwynfynnydd mine, adjoining the Cain and Mawddach rivers. He said he brought before the Section as mineralogical facts:—that of the change of the crystal, that the gold where the crystal was found is of 14 carats fine only, that from the quartz-lode at Gwynfynydd 18 carats fine, and the water-worn gold from the Cain and Mawddach 23 carats fine—giving them as facts open to a good deal of interesting speculation.

On Sections of Strata between Huyton and St. Helen's.
By Charles Ricketts, *M.D., F.G.S.*

The exposures made in the formation of the new railway between Huyton and St. Helen's, whilst confirming the general accuracy of the maps of the Geological Survey, have disclosed important features which would not otherwise have been determined.

In the Lower Coal-measures or Gannister beds, a little north of, but somewhat lower in the series than, those in Huyton Quarry, a succession of beds of sandstone, shales, and clay was displayed, surmounted by a bed of coal a foot and a half thick, probably the equivalent of the "Mountain Mine" coal formerly worked at Knowsley.

As the line to the south of Prescot crosses the Upper Coal-measures, several outcrops of coal are exposed, viz. "the Bastions," in the situation marked upon the map; a bed called in the six-inch map "Little Delf," and the "Sir John" coal, about one hundred yards to the eastward of the places given from information as the position of their outcrop; and at the site proposed for the Prescot Station, the two beds constituting the "Prescot Main" coal, a short distance beyond which, and sixty yards from the Rainhill road, a considerable north and south fault occurs, not marked upon the map, which throws down to the east purple and mottled sandstones and shales of upper beds of the Coal-measures; these continue as far as the Survey boundary fault, by which the Lower Bunter is thrown down to the east.

As on the formation of the Liverpool and Manchester Railway the presence of Coal-measures was discovered near Whiston, so likewise in a situation marked upon the maps as Lower Bunter, there occur two small areas of purple Coal-measure strata similar to those near the Rainhill road, having intervening beds of Triassic sandstone, which have been thrown down by faults.

The boundary fault of the St. Helen's Coal-field is seen at Thatto Heath, having an intermediate step-fault on the west or downthrow; it has likewise caused a considerable amount of fracture and displacement in the Pebble-beds or Middle Bunter. The Sutton-Heath fault is crossed by the railway where the two beds forming the "Ravenhead" coal are cut off on its downthrow; a little below the lower or "main" coal trees were seen *in situ*, and the Rev. H. H. Higgins has obtained from the same locality numerous specimens of the stems, leaves, and fruits of *Calamites*, and also of *Lepidodendron*, with ferns &c.; also a beautifully preserved wing of an Orthopterous insect: these have been deposited in the Liverpool Museum.

At the entrance to the deep cutting in the Pebble-beds near Scholes Farm, wherever the surface is covered with the sands and clays of the Boulder-clay period, it remains beautifully planed, grooved, and striated, the striæ being from south-east to north-west.

In the Lower Bunter sandstone, previously alluded to, there are several fissures without much displacement of the beds, the interstices being filled with a *débris*

consisting of subangular and rounded fragments from the Coal-measures and the Triassic sandstone, as well as liver-coloured and quartz pebbles from the Middle Bunter, and likewise granite, porphyry, greenstone, and other pebbles derived from the Boulder-clay, one of which affords an excellent example of glacial markings. It may therefore be inferred that these fissures must have been formed during the recent or at least the postglacial period.

Mr. C. Smith exhibited an Orthopterous insect.

On the recent Formation of Gravel-beds resembling Middle Drift. By G. JOHNSTONE STONEY, *M.A., F.R.S.*

On the east coast of Ireland, extending south of Dublin from Killiney to Bray Head, and from Bray Head to Greystones in the county Wicklow, there are considerable cliffs of Drift exposed to view. They consist of (1) masses of amorphous glacial clay, usually containing an abundance of striated limestone boulders and fragments of shells; (2) gravel, which is almost unstratified, containing a few striated boulders and fragments of shells; and (3) stratified beds of gravel and sand, without striated boulders and with but very few fragments of shells. The stratified beds have usually been regarded as Middle Drift, the other beds being treated as Upper Glacial Drift or Lower Glacial Drift, according to their position.

The author had carefully examined these formations from Bray Head to a little south of Greystones, and had satisfied himself that the undoubtedly glacial deposits are to the present day in process of being transformed into the stratified beds of gravel and sand, which have been usually referred to Middle Drift.

The Drift rests directly on argillaceous slates of the Cambrian formation; and the first thing which attracted attention was that all the spring water of the neighbourhood is hard, containing an abundance of salts of lime. These could only have been obtained from the limestones of the Drift, and consequently indicated that a sensible amount of change is going on in it. This led the author to investigate further, and he then found evidences of change everywhere and unmistakable. But it will be most useful to confine this record to the appearances in two situations, which can be without difficulty identified by any person who may wish to reexamine the ground.

Under the railway station at Greystones, which is built close to the shore, a cliff of glacial clay with abundance of striated boulders will be found. It rests directly on the Cambrian slates, which are also exposed to view. Immediately in front of the railway station the clay reaches to the surface of the ground; but 80 or 100 yards further south beds of stratified gravel will be found above it, the stratification being usually oblique to the surface of contact of the gravel and clay. Here it will be easy to see evidence that rain when it falls soaks quickly through the gravel, and then travels along the upper surface of the clay. In doing so it penetrates the clay to a certain distance, from 2 to 6 inches, altering its colour from a dirty blue, which is the prevailing colour of the glacial clay at this spot, to a light fawn colour. If this stratum of clay out of which the colour has been discharged be dug into, the remains of limestone boulders will be found scattered through it, which have also been attacked by the water. There usually remains either a powdery mass of the insoluble matter of the boulder, or such a mass with a core of some fantastic shape, which is the part of the limestone that has not yet been dissolved away. In a few instances specimens were found in which one side of the stone had been sheltered from the water, and still retained its glacial markings. Moreover some of the clay is washed forwards when the water travels over it, for wherever the water dribbles out at the surface of the cliff it carries clay out with it. Here, then, we have an instance in which the so-called Lower Glacial Drift is being in part corroded or washed away all over its upper surface; and the portions that remain are being added on to the lower surface of the overlying Middle Drift. The part which is being converted into Middle Drift appears to consist principally of the insoluble stones of the glacial clay, and of such central portions of the larger limestones as may outlive the corroding process.

At this station, wherever the rock is exposed to view, water will be found also, oozing out here and there from the face of the cliff between the glacial clay and the underlying rock. Where this occurs, abundant specimens of the corroded limestones are to be met with; and no doubt if the passage of water were sufficiently prolonged, it would in time lead inevitably to the formation of gravel-beds between the clay and the rock. But the percolation which was observed appears to be of too modern a date. It probably began after the existing cliff was formed by the advance of the sea.

A case, however, in which Upper Glacial Drift has undoubtedly been converted into Middle Drift, will be found at the south end of the Ladies' Bathing-place at Greystones. Here the upper part of the cliff consists of glacial clay with a few striated boulders, and below it there are imperfectly stratified beds of sand and gravel. These porous beds communicate with the surface-soil by means of a chimney-like passage filled with gravel, which is exposed in the cliff, and through which rain gained access to the beds below. These beds bear evidence that, before they were cut across by the sea, they formed part of a subterranean reservoir, in which slowly flowing water was confined between the rocks beneath and the glacial clay above, the lowest layer of the glacial clay to the depth of several inches having acquired a structure which is stratified parallel to its under surface. This stratified structure is continued along the clay walls of the passage by which the rain had access to the porous beds. In this case the corroding and transporting action of the water upon the underside of the glacial drift has probably been suspended since the subterranean reservoir was tapped by the encroachment of the sea; but the appearances clearly show that it had before that time been going on, that the water in its passage had been corroding or carrying away some constituents of the Upper Glacial Drift over its under surface, and that the residue which remained became an accession to the underlying beds of gravel and sand.

These particular spots have been pointed out, because they can be easily identified by other observers; and abundant confirmatory evidence will be found all along the three miles of coast examined by the author. In some places isolated masses of clay will be found in the gravel-beds, which may be presumed to be outstanding portions of the glacial clay; and in all places the ratio of the limestones to the other kinds of stone is much less in the gravel-beds than in the glacial clays, which is the state of things that would naturally arise if the gravel-beds have been wholly formed out of glacial deposits by the prolonged action of the causes which we find still in operation.

There is also evidence to show that the stratification of the gravel-beds is due to causes still existing; for in the places where there is the most unmistakable evidence that Middle Drift is to this day being formed at the expense of glacial drift, it was found that the stratification of the gravel-beds was continued almost into contact with the glacial clay, and therefore through the parts most recently converted. But this need present no difficulty. An old mill-race, with a mound along one side of it, has lately been removed to make way for the extension of Dublin towards Sandymount. The mound when cut across presented as fully developed a stratified structure as is usually seen in natural gravel-beds. And what made the case conclusive was that the distribution of the materials was in most places wholly different both in kind and degree from what the original piling of them together could have occasioned. It must therefore have been produced subsequently, and it was interesting to observe most of the main features of natural stratification reappearing in it, with their unconformable beds, separation of fine from coarse materials, and so on.

A very simple experiment will show how much may be effected even in a short time by the percolation of water through gravel-beds. Pour a few cans of water upon sand which consists of particles of various degrees of fineness, and if a little cliff be then made in the wet sand, it will be found to be already stratified in a very considerable degree.

On the Physical Geology of the Bone-caves of the Wye. *By the* Rev. W. S. Symonds, *M.A., F.G.S.*

Fossil bones of the exinct mammalia have been discovered in "King Arthur's Cave," situate in Great Doward Wood, on the right bank of the Wye, between Whitechurch, near Ross, and Monmouth. They were forwarded to Prof. Owen, and were determined by him to be molar teeth of *E. primigenius*, molar teeth of *Rhinoceros tichorhinus*, gnawed astragalus and bones of *R. tichorhinus*, molar teeth and bones of *Equus fossilis*, upper molar and astragalus of *Bos primigenius*, shed antler of Reindeer (*Cervus tarandus*), right upper canine of *Hyæna spelæa.*

These fossil bones are from a cavern in a locality rich in caves in the mountain limestone, now elevated to a considerable height above the river Wye, but in which fossil bones of the extinct mammalia had not hitherto been found.

Arthur's Cave has evidently been the den of the great Cave Hyæna, as evinced by the gnawed state of many of the bones, and the remains of that animal itself. The physical geology of the district was described by the author of the paper.

On the Occurrence of Seams of Hard Sandstone in Middle Drift of East Anglia. *By* J. E. Taylor.

A Census of the Marine Invertebrate Fauna of the Lias. *By* Ralph Tate, *F.G.S.*

On the Diamonds of South Africa. *By* J. Tennant, *F.G.S.*

On the Occurrence of Pebbles and Boulders of Granite in Schistose Rocks in Islay, Scotland. *By* James Thomson, *F.G.S.*

The author described the different rocks exhibited in a section across Islay, from Port Nahaven on the west to Port Askaig on the east, which principally consist of gneiss, chlorite and mica-schist, quartzites and limestone. There is a diversity of opinion as to the proper position of these rocks; some consider them of Laurentian, while others think they are of Cambrian age. The author was inclined to think they belonged to the latter period. At Port Askaig there is a precipitous cliff of quartzite about 70 feet in height, made up of about one hundred thin bands varying from 1 to 20 inches in thickness. Underlying this quartzite there is a mass of arenaceous talcose schist, showing faint traces of stratification, containing fragments, some angular but mostly rounded, of all sizes, from mere particles to great boulders of granite, resembling the granite of the Island of Mull. Similar rocks do not occur in the Island of Islay; and Mull being at a considerable distance to the north, with a deep sea between the two islands, he suggested the probability of the granite having been transported by the agency of ice.

These deposits resemble the boulder drifts of more recent times, in the following respects:—first, in the absence of stratification in one part of the section, which in another shows signs of regular deposition; secondly, in the close proximity of fragments of far transported rock, varying in size from minute fragments to large boulders; the origin he ascribed to the mass having been deposited in a tranquil sea of mud, sand, and blocks from melting drift-ice. The absence of stratification in one part of the section while it is present in another, may be accounted for by the disturbing action of icebergs, when stranded in the soft plastic mass, in parts of the sea of limited depth. He also stated that pebbles of granite had long been sought for in the conglomerates of the Old Red Sandstone; but in no part of Scotland had it been found in rocks of that age, consequently it was inferred that the granite of Scotland was posterior to the deposition of the rocks belonging to that period. The discovery of fragments and boulders of granite imbedded in these deposits, furnish adequate proof that the age of granite cannot be restricted, and that glacial action was not limited to any special geological period.

On a Diagram of the Earth's Eccentricity and the Precession of the Equinoxes, illustrating their Relation to Geological Climate and the Rate of Organic Change. By ALFRED R. WALLACE, *F.R.G.S.*

The author exhibited a diagram of the eccentricity of the earth's orbit and the precession of the equinoxes, from which he deduced certain important views as to the climates of past geological ages and the changes of organic life. During the past three million years the eccentricity has been almost always much greater than at present, on the average twice as great, and for long periods more than three times as great. It was shown that when the eccentricity was greatest the heat received from the sun at the greatest and least distances was as 3 to 4; and, owing to the precession of the equinoxes, the winters of the northern hemisphere would be rendered intensely cold and much longer for periods of 10,500 years, while during the alternate periods the winters would be mild and short, the summers cool and long, leading to an almost perpetual spring. We thus have cold or glacial epochs for about 10,000 years, alternating with mild epochs for the same period, whenever the eccentricity was high, and this was the case for fully the half of the last three million years; and, as such alternations must have occurred during every glacial epoch, the fact of intercalated warm periods and the migrations consequent on them, which have been detected by geologists, must be looked upon as the normal condition of things. But during the last 60,000 years (probably the whole time elapsed since the close of the last glacial epoch) the eccentricity has been very small, and the alternations of climate and consequent migrations very slight; and as Mr. Darwin holds that alternations of climate are, by means of the consequent migrations, the most powerful cause of modifications of species, there must have been a comparative stability of species during that period of time, from which alone we obtain our idea of the rate of specific change. This idea will therefore be erroneous; and the rate of change during past geological ages may have been, and probably was, much more rapid than has hitherto been thought possible. During three million years before and one million after the recent epoch, no less than 130 alternations of climate occurred (each of 10,000 years' duration), when the eccentricity was more than double what it is now; and these incessant changes were thought, on Darwinian principles, to supply a *vera causa* for a rapid change of species, and thus enable us considerably to reduce the duration of geologic periods, which had heretofore been measured by data derived from the period of organic stability since the last glacial epoch.

On the Organization of the Stems of Calamites. *By* Professor W. C. WILLIAMSON, *F.R.S.*

The author pointed out the unity of type observed amongst the British Calamites, and the consequent improbability of the existence anywhere of two types (the one Cryptogamic, the other Gymnospermous), as believed by Prof. Adolphe Brongniart. He then described the various portions of the jointed stem, the centre of which is a cellular ring of fistular pith, having transverse dissepiments at the nodes. Around this is a woody zone, composed of wedges of barred and reticulated vessels. These wedges are separated from each other by large medullary rays, and smaller rays separate the constituent laminæ of each wedge, which latter spring at their innermost angle from a longitudinal canal running from node to node. The organization of these wedges, canals, and medullary rays was described in minute detail, their variations in several species being noted, as well as the differences between the arrangement at the nodes and at the internodes, which differences are often very characteristic. The structure of the epidermal layer, or bark, was then shown to be cellular; it consisted of an irregular parenchyma, with cells of variable dimensions. Its exterior appears to have been smooth, unlike the exterior of the woody groove zone, which, like the interior of the latter portion, was longitudinally fluted, the longitudinal ridges and furrows of each internode usually alternating at the nodes. The branches were shown to be of small size, being given off from the woody wedges exactly opposite the centre of each node, whilst the roots were described as originating from the lower extremity of each of the internodes at the

base of the stem. The specimens with large branches sometimes met with, were shown to belong to the subterranean rhizomes.

The author then demonstrated the nature of the arenaceous and argillaceous casts found in the shales and sandstones of the coal-measures. He pointed out that these were casts of medullary cavities, formed after an almost complete absorption of the medullary cells had taken place. In one type, designated by the generic name of *Calamopitus*, these cavities were prolonged through the woody zone to the bark, in the shape of a verticil of narrow canals occupying the upper part of each internode, but located below and distinct from the true branches. The parallel longitudinal grooves seen in the common specimens indicate the positions of the longitudinal canals, whilst the intermediate ridges correspond with those of the large medullary rays separating the woody wedges. The carbonaceous covering usually found adhering to these casts was described as throwing little or no light upon the organization of these plants, and as being, consequently, a most treacherous guide to their real nature and affinities. The general growth of the woody zone was shown to be exogenous, corresponding closely with that seen in the shoot of the first year of an ordinary gymnospermous exogen. But the fructification of these plants was proved to be cryptogamic. Hence we have in them a combination of which no perfect parallel is seen amongst living plants. The author recognized the close affinities of the Calamites with the living Equisetaceæ, but urged that they should be divided into two genera, *Calamites* and *Calamopitus*, and made into an allied but distinct family of Calamitaceæ, and not actually incorporated with the Equisetaceæ.

On the Palæontological Aspects of the Middle Glacial Formation of the East of England, and on their bearing upon the Age of the Middle Sands of Lancashire. By SEARLES V. WOOD, *F.G.S., and* F. W. HARMER, *F.G.S.*

The design of this paper was to caution the geologists of Lancashire against too hastily correlating the sands termed the Middle Sands of Lancashire, in consequence of their being intercalated between the upper and lower boulder-clays of that county, with the deposits of East Anglia, for some time described under the term Middle Glacial. It was shown that while in the Lancashire deposits, as at present investigated, none but recent shells had been found, the Middle Glacial deposits contained several extinct crag forms. Whilst abstaining from expressing any decided opinion as to the exact age of the Lancashire beds, it was pointed out that the evidence at present obtained would lead to the belief that they were much more recent than the Middle Glacial of the east coast, and not improbably of the age of the Hessle gravel of Yorkshire (the fossils of which occur at Paull and Kelsea in Holderness), a postglacial deposit which is overlain by postglacial boulder-clay called the "Hessle clay." The shells of the middle sands at Blackpool Cliff, in Lancashire, are very slightly fossilized, whereas those of the east of England beds are as thoroughly fossilized as those of the Crag. Two lists of species obtained by the authors from the East-Anglian Middle Glacial were given,—one of *certain* identifications, and the other of identifications more or less doubtful from the fragmentary condition of the specimens. The former list contained the following, viz. *Buccinum undatum*, var. *tenerum*, *Trophon muricatus*, *Fusus antiquus* (dextral form), *F. scalariformis*, *Purpura lapillus*, ditto var. *incrassata*, *Nassa incrassata*, *N. granulata*, *N. pusio* (a new crag species), *Mangelia turricula*, *M. exarata*, *M. linearis*, *Natica clausa*, *N. catena*, *N. helicoides*, *N. Alderi*, *Scalaria Trevelyana*, *S. Grœnlandica*, *Turritella incrassata* (*triplicata* of Brocchi), *T. terebra*, *Cerithium tricinctum*, *Chemnitzia internodula*, *Odostomia unidentata*, *Rissoa inconspicua*, *Littorina litorea*, *L. rudis*, *Margarita undulata*, *Capulus Hungaricus*, *Calyptræa sinensis*, *Dentalium dentalis*, *Anomia ephippium*, *Pecten opercularis*, *P. pusio*, *P. varius*, *Mytilus edulis*, *Pectunculus glycimeris*, *Limopsis pygmæa*, *Nucula Cobboldiæ*, *N. nucleus*, *Leda limatula*, *Cardium edule*, *Cardita scalaris*, *Loripes divaricatus*, *Lucina borealis*, *Astarte borealis*, *A. sulcata*, *A. compressa*, *A. Burtinii*, *A. Omalii*, *Erycinella ovalis*, *Tapes* (either *virgineus* or *pullastra*), *Cytherea rudis*, *Cyprina islandica*, *Venus fluctuosa*, *V. fasciata*, *V. ovata*, *Tellina obliqua*, *T. Balthica*, *T. crassa*, *Scrobicularia piperata*, *Mactra*

ovata, Mya arenaria, Saxicava arctica, Pholas crispata, Corbula nucleus, Pandora inæquivalvis, and three small species of *Trophon* and one of *Mangelia* that are new.

Of the above shells (70 in number) only two (exclusive of the *Mangelia* and of the three small new *Trophons*) have not occurred in either the Coralline Red or Norwich Crags, viz. *Venus fluctuosa* and *Tellina Balthica*; while eight of them (exclusive of the four new forms), viz. *Purpura incrassata, Nassa granulata, N. pusio, Cerithium tricinctum, Astarte Burtinii, A. Omalii, Erycinella ovalis,* and *Tellina obliqua,* are not known as living shells; and two, viz. *Nucula Cobboldiæ* and *Cardita scalaris,* are, if living, confined to the Pacific.

The uncertain list comprised the following, viz. *Trophon consocialis, Nassa reticosa, Trochus granulatus, T. zizyphinus, Astarte incrassata, A. gracilis, Cytheræa chione, Fissurella græca, Emarginula* ——?, *Columbella sulcata, Margarita helicina, Tellina lata, Mactra subtruncata, M. arcuata, Leda lanceolata,* and *Mya truncata,* all Crag shells, and five of them not known living. Especial attention was called to the presence of such a shell as *Erycinella ovalis,* of which three specimens had been obtained. Two Crag corals, viz. *Sphenotrochus intermedius* and *Balanophyllia calyculus,* had also occurred. The character of the fauna was Southern rather than Northern.

Notes on Fossil Crustacea. By HENRY WOODWARD, *F.G.S.*

Mr. Woodward first called attention to the progress made in the investigation of this class during the past year. He referred to the important discovery of legs in *Asaphus* (made by Mr. E. Billings) as likely to decide the position of the Trilobites to be near the *Isopoda,* and not near the *Phyllopoda,* as heretofore supposed.

The progress of investigation of the larval stages of *Limulus* promises also to throw important light on the older forms of this group, and also upon the relation between the *Limuli* and *Trilobitæ.*

Mr. Woodward described the following new Crustacea, namely:—

1. A new species of *Eurypterus* (*E. Brodiei*) from the Upper Ludlow, Stoke-Edith Purton, discovered by the Rev. P. B. Brodie, M.A., F.G.S.

2. A new and gigantic Phyllopod (*Ceratiocaris ludensis*) from the same formation near Ludlow, preserved in the Ludlow Museum.

3. A new *Ceratiocaris* (*C. Oretonensis*) from the Carboniferous limestone of Oreton, Worcestershire.

4. Four new forms of *Cyclus* from the Carboniferous limestone of Ireland and Yorkshire, namely, *C. bilobatus, C. torosus, C. Wrightii, C. Harknessi.* Mr. Woodward remarked upon the singular mimetic resemblance between these shields and the young larval land-crabs figured by Mr. Westwood in the Philosophical Transactions, p. 311 (1835).

5. A new Isopod from the Lower Chalk of Dover, Luton, and Ely was described under the name of *Palæga Carteri.*

6. A second species of *Scyllaridia* (*S. Bellii*) was recorded from the London Clay of Sheppey.

7. Lastly, Mr. Woodward described a new form of *Dithyrocaris* (*D. striatus*), obtained by Principal Dawson, of Montreal, from the Middle Devonian Sandstone of Gaspé, Canada.

BIOLOGY.

Address by Professor ROLLESTON, *M.D., F.R.S., President of the Section.*

AMONGST the duties of a President of a Section the delivery of an Address has in these latter days somehow come to be reckoned; and that I may interpose myself for but as short a time as possible between your attention and the papers announced to you for reading upon your list, I will begin what I have to say without any further preface.

I wish first to make a few observations as to the kind of preparation which is

indispensable, as it seems to me, as a preliminary to an adequate and intelligent comprehension of the problems of biology; or, in other words, to an adequate and intelligent comprehension of the discussions which will take place in this room and in the two other rooms which will be assigned to, and occupied by, the department of Ethnology and Anthropology, and that of Physiology pure and proper, with Anatomy.

Having made these observations, I propose, in the second place, to enumerate the subjects which appear likely to occupy prominent places in our forthcoming discussions; and thirdly, I will, if your patience allows me, conclude with some remarks as to certain of the benefits which may be expected, as having been constantly observed to flow from a due and full devotion to biological study.

In the first place, then, I wish to say that though the problems of biology have much of what is called general interest (that is to say, of interest for all persons) attaching to them,—as, indeed, how could they fail to have, including as they do the natural history of our own and of all other species of living organisms, whether animal or vegetable?—some special preparation must be gone through if that general interest is to be thoroughly and intelligently gratified. I would compare the realm of biology to a vast landscape in a cultivated country of which extensive views may be obtained from an eminence, but for the full and thorough appreciation of which it is necessary that the gazer should himself have cultivated some portion, however small, of the expanse at his feet. It is, of course, a matter of regret to think that persons can be found who look upon an actual landscape without any thought or knowledge as to how the various factors which make up its complex beauty have come to cooperate, how the hand of man is recognizable here, how the dip of the strata is visible there, and how their alternation is detectable in another place as the potent agency in giving its distinctive features; but I take it that real and permanent, however imperfect, pleasure may be drawn from the contemplation of scenery by persons who are ignorant of all these things. I do not think this is the case when we here deal with *coup d'œil* views of biology. The amount of the special knowledge, the extent of the special training need not necessarily be great; but some such special knowledge and training there must be if the problems and argumentations familiar to the professed biologist are to be understood and grasped by persons whose whole lives are not devoted to the subject, so as to form for them acquisitions of real and vital knowledge.

The microscope has done very much (indeed I may say it has done almost all that is necessary) for enabling all persons to obtain the necessary minimum of practical and personal acquaintance with the arrangements of the natural world of which I am speaking. The glass trough used in Edinburgh, the invention of John Goodsir, whose genius showed itself, as genius often does show itself, in simple inventions, can be made into a miniature aquarium (I purposely use a word which calls up the idea of an indoors apparatus, wishing thereby to show how the means I recommend are within the reach of all persons); and in it, lying as it does horizontally and underlain as it is by a condenser, animal and vegetable organisms can be observed at any and at all hours, and continuously, and with tolerably high magnifying-powers even whilst undisturbed. Thus is gained an admirable field for the self-discipline in question. The microscope which should be used by preference for exploring and watching such an aquarium should be such a one as is figured in Quekett's work on the Microscope (p. 58, fig. 36), as consisting of a stem with a stout steadying base, and of a horizontal arm some 9 inches long, which can carry indifferently simple lenses or a compound body. I think of the two it is better that the aquarium should be horizontal rather than the microscope; and those who think with me in this matter can nevertheless combine for themselves the advantages of the horizontal position of the instrument with those of the horizontal position of the objects observed by modifying the eyepiece in the way figured by Quekett (p. 381, fig. 266). It would be a long task to enumerate fully all the scientific lessons which may be gathered, first, and all the educational agencies, secondly, which may be set and kept in movement by a person who possesses himself of this simple apparatus. The mutual interdependence of the animal and vegetable kingdoms, their *solidarité* as the French have called it, and as the Germans have called it too, copying herein the French, is one of the first lessons the observer has forced

upon him; the influence of physical and chemical agencies upon the growth and development of living beings he soon finds strikingly illustrated; the mysterious process of development itself is readily observable in the eggs of the common water-snails and in those of freshwater fish, so that the way in which the various organs and system of organs are chiselled out, built up, and finally packed together and stratified can be taken note of in these yet transparent representatives of these great subkingdoms which all the while are undisturbed and at peace: and all these points of large interest are but a few of many which these small means will enable any one to master for himself in the concrete actuality, and thoroughly. The necessity for carefulness and truthfulness in recording what is seen, the necessity for keeping in such records what one observes quite distinct from what one infers, the necessity for patience and punctuality, are lessons which, from having a moral factor as well as a scientific one in their composition, I may specify as belonging to the educational lessons which may be gathered from such a course of study.

I have been speaking of the microscope as an instrument of education, and I wish before leaving the subject to utter one caution as to its use when this particular object of education is in view. If a subject is to act educationally, it must be understood thoroughly; and if a subject is to be understood thoroughly, it must form one segment or stretch in a continuous chain of known facts. *Ἀρκτέον ἀπὸ τῶν γνωρίμων*, said one of the greatest of educators; you must start from some previously existing basis of knowledge, and keep your communications with it uninterrupted if your knowledge is not to be unreal. And my concrete application of these generalities is contained in the advice that no sudden jump be made from observations carried on with the naked eye to observations carried on with the highest powers of the microscope. I am speaking of the course to be pursued by beginners, and beginners we all were once; and if our places are to be filled (and filled they will be), by better men, as we hope, than ourselves, they will have to be filled, we also hope, by men who have yet to become beginners. It is in their interest I have been speaking; and I say that a beginner does not ordinarily get an intelligent conception of the revelations of the microscope except in Bacon's words, *Ascendendo continenter et gradatim*, by progressing gradually from observations with the naked eye through observations dependent upon dissecting-lenses, doublets by preference, and the lower powers of the compound microscope, up to observations to be made with the higher and highest magnifying-powers. Unless he ascends by gradations from organs and systems to structures and tissues and cells, his wonder and admiration at the results of the ultimate microscope analysis, of what he had but a moment before knowledge of only in the concrete and by the naked eye, is likely to be but unintelligent.

There are three other agencies which can be set into activity with nearly as little trouble and difficulty as the simple apparatus of which I have been just been speaking, and which will, like it, secure for us the necessary preliminary discipline or "*Propädeutik*" for the rational comprehension of Biology. These are Local Museums, Local Field Clubs, and Local Natural Histories. Local authorities, persons of local influence, should engage and interest themselves in the starting into life of the two former of these agencies; and if some such person as Gilbert White could be found in each county to write the Natural History of its Selborne, I know not at what cost it would not be well to retain his services. As the world is governed, upon each particular area of its surface there is to be found a certain percentage of the population occupying it who have special calls for particular lines of study. It is the interest of each country to have such means and such institutions in being as will render it possible to detect the existence of persons gifted with such special vocations, to give the talent thus entrusted to them fair scope for development, and to render smaller the risk of their dying mute and inglorious. A young man who is possessed of a talent for Natural Science and Physical Inquiry generally, may have the knowledge of this predisposition made known to himself and to others, for the first time, by his introduction to a well-arranged Local Museum. In such an institution, either all at once, or gradually, the conviction may spring up within him that the investigation of physical problems is the line of investigation to which he should be content to devote himself, relinquishing the pursuit of other things; and then, if the museum in question

really a well-arranged one, a recruit may be thereby won for the growing army of physical investigators, and one more man saved from the misery of finding, when he has been taken into some other career, that he has, somehow or other, mistaken his profession, and made of his career one life-long mistake.

Here comes the question, What is a well-arranged museum? The answer is, a well-arranged museum, for the particular purpose of which we are speaking, is one in which the natural objects which belong to the locality, and which have already struck upon the eye of such a person as the one contemplated, are clearly explained in a well-arranged catalogue. The curiosity which is the mother of science is not awakened for the first time in the museum, but out of doors, in the wood, by the side of the brook, on the hillside, by scarped cliff and quarried stone; it is the function of the museum, by rendering possible the intellectual pleasure, which grows out of the surprise with which a novice first notes the working of his faculty of inspiration, to prevent this curiosity from degenerating into the mere woodman's craft of the gamekeeper, or the rough empiricism of the farmer. The first step to be taken in a course of natural instruction is the providing of means whereby the faculties of observation and of verification may be called into activity; and the first exercise the student should be set down to is that of recognizing, in the actual thing itself, the various properties and peculiarities which some good book or some good catalogue tells him are observable in it. This is the first step, and, as in some other matters, *ce n'est que le premier pas qui coûte.* And it need not cost much. There is a name familiar to Section D, and, indeed, not likely for a long while to be forgotten by members of the British Association generally, extrinsic means as well as the intrinsic merits of the well-loved man conspiring to keep his memory fresh among us, and the bearer of that name, Edward Forbes, has left it as his opinion that "It is to the development of the provincial museums that, I believe, we must in future look for the extension of intellectual pursuits throughout the land." (Lecture "On the Educational Uses of Museums," delivered at the Museum of Practical Geology and published in 1863. Cited by Toynbee, "Hints on the Formation of Local Museums," 1863, p. 46.) With the words of Edward Forbes I might do well to end what I have to say, but I should like to say a word as to the policy of confining the contents of a local museum to the natural-history specimens of the particular locality. No doubt the first thing to be done is the collection of the local specimens, and this alike in the interest of the potential Cuviers and Hugh Millers who may be born in the district, and in the interest of the man of science who may visit the place when on his travels. But so long as a specimen from the antipodes or from whatever corner of our world be really valuable, and be duly catalogued before it is admitted into the museum, so that the lesson it has to teach may be learnable, I do not see my way towards advising that foreign specimens be excluded. It is to my mind more important that all specimens should be catalogued as soon as received, than that any should be rejected when offered.

I must not occupy your time further with this portion of my address. Let me first say that a person who wishes to know what a Field-Club can do for its members, and not for them only, but for the world at large, will do well to purchase one, or any number more than one, of the Transactions of the Tyneside Naturalist's Field-Club; and that if there be any person who thinks that White's 'Selborne' relates to a time and place so far off that there can be no truth in the book, and who yet would like to try upon himself the working of the fourth disciplinary agencies of which I have spoken, that, namely, of reading some local Natural History on the spot of which it treats, and comparing it with the things themselves *in situ*, let him repair to Weymouth, and work and walk up and down its cliffs and valleys with Mr. Damon's book in his hands.

I shall not be suspected in this place and upon this occasion, nor, as I hope, upon any other, of a wish to depreciate the value of scientific instruction as an engine for training the mind; but neither, on the other hand, should I wish to depreciate the value of literary culture, my view of the relations of these two gymnastics of the mind being the very simple, obvious, and natural one that they should be harmoniously combined—

Alterius sic
Altera sic poscit opem vis, et conjurat amice.

I know it may be said that there are difficulties in the way, and especially practical difficulties; but I have always observed that people who are good at finding out difficulties, and especially practical difficulties, are like people who are good at finding out excuses,—good at finding out very little else. The various ways of getting over these difficulties are obvious enough, and have been hinted at or fully expressed by several writers of greater or less authority on many occasions. It is, however, of some consequence that I should here say what I believe has not been said before, namely, that a purely and exclusively literary education, imperfect and one sided as it is, is still a better thing than a system of scientific instruction (to abuse the use of the word for a moment) in which there should be no courses of practical familiarizing with natural objects, verification, and experimentation. A purely literary training, say, in dialectics, or what we are pleased to call logic, to take a flagrant and glaring instance first, does confer certain lower advantages upon the person who goes through it without any discipline in the practical investigation of actual problems. By going through such a training attentively, a man with a good memory and a little freedom from over-scrupulousness, can convert his mind into an arsenal of quips, quirks, retorts, and epigrams, out of which he can, at his own pleasure, discharge a *mitraille* of chopped straw and chaff-like arguments, against which no man of ordinary fairness of mind can, for the moment, make head. It is true that such sophists gain this dexterity at the cost of losing, in every case, the power of fairly and fully appreciating or investigating truth, of losing in many cases the faculty of sustaining and maintaining serious attention to any subject, and of losing in some cases even the power of writing. A well-known character in an age happily, though only recently, gone by, who may be taken as a Cæsar worthy of such Antonies, used to speak of a pen as his torpedo. Still they have their reward, they succeed now and then in convincing juries, and they are formidable at dinner-tables. It would not be fair, however, not to say that a purely literary training can do much better things than this. By a purely classical education a man, from being forced into seeing and feeling that other men could look upon the world, moral, social, and physical, with other (even if not with larger) eyes than ours, attains a certain flexibility of mind which enables him to enter into the thoughts of other and living men; and this is a very desirable attainment. And, finally, though I should be sorry to hold with a French writer that the style makes the man, the benefit of being early familiarized with writings which the peculiar social condition of the classical times, so well pointed out by De Tocqueville (De la Démocratie en Amérique, i. 15), conspired and contributed not a little to make models of style, is not to be despised. Such a familiarity may not confer the power of imitating or rivalling such compositions, but it may confer the power of appreciating their excellences, the one power appearing to us to be analogous to the power of the experimenter, and the other to that of the pure observer in Natural Science; and we should undervalue neither.

Masters of Science, it must be confessed, are not always masters of style; let not the single instance of last night tempt you to generalize, it was but a single instance, the writings of the man whom we in this Section are most of us likely to look upon as our master in Science have been spoken of by our President in his recently published volume as "intellectual pemmican;" and if scientific reading and teaching is to be divorced from scientific observation of natural objects and processes, it is better that a man, young or old, should have in his memory something which is perfect of its kind, entire and unmutilated, such as the opening sentences of the 'Brutus' of Cicero, which Tacitus, I think, must have had in his memory when he wrote his obituary of Agricola, or as the opening sentences of the 'Republic' of Plato, or the conclusion of the 'Ajax' of Sophocles, than that he should have his memory laden with a consignment of scientific phrases which, *ex hypothesi*, have for him no vital reality. I have already said that I am strongly of opinion that literary should always be combined with scientific instruction in a perfect educational course; these somewhat lengthy remarks refer therefore only to systems in which it is proposed that we should have not only a bifurcation but a radical separation of studies and students; and the moral of this may be summed up by saying that a purely scientific education must be a thoroughly practical one, familiarizing the student with actual things as well as with words and symbols.

It was upon the solid ground that Antæus learnt the art of wrestling; it was only when he allowed himself to be lifted from it that he was strangled by Hercules.

Coming, now, to the second part of my address, I beg to say that the word Biology is at present used in two senses, one wider, the other more restricted. In this latter sense the word becomes equivalent to the older, and till recently more currently used word "Physiology." It is in the wider sense that the word is used when we speak of this as being the Section of Biology: and this wider sense is a very wide one, for it comprehends, first, Animal and Vegetable Physiology and Anatomy; secondly, Ethnology and Anthropology; and thirdly, Scientific Zoology and Classificatory Botany, inclusively of the Distribution of Species. It may have been possible in former times for a single individual of great powers of assimilation to keep himself abreast of, and on a level with, the advance of knowledge along all these various lines of investigation; but in those times knowledge was not, and could not, owing to difficulties of intercommunication, the dearness of books, the costliness or the non-existence of instruments, have been increased at the rate at which it is now being, year by year, increased; and the entire mass of actually existing and acquired knowledge was of course much smaller, though man's power of mastering it was no smaller than at present. It would now be an indication of very great ignorance if any body should pretend that his own stock of information could furnish him with something in each one of the several departments of knowledge I have just mentioned, which should be worthy of being laid before such an assembly as this. As will have been expected, I shall not presume to do more than glance at the vegetable kingdom, large as is the space in the landscape of life which it makes. What I do propose to do is merely to draw your attention to a very few of the topics of leading interest, which are at the present moment being, or rather will shortly begin to be, discussed by experts in the Department of Physiology and Anatomy, in the Department of Ethnology and Anthropology, and, thirdly, in the Department of Scientific Zoology.

Under the head and in the Department of Physiology proper and Anatomy, our list of papers and, I am happy to add, the circle of faces around us suggest to us the following subjects as being the topics of main interest for the present year:—the questions of Spontaneous Generation; that of the influence of organized particles in the production of disease; that of the influence of particular nervous and chemical agencies upon functions; that of the localization of cerebral functions; that of the production and, indeed, of the entire *rôle* in the economy of creation of such substances as fat and albumen; and, finally, that of the cost at which the work of the animal machine is carried on.

The question of Spontaneous Generation touches upon certain susceptibilities which lie outside the realm of science. In this place, however, we have to do only with scientific arguments, and I trust that the Section will support the Committee in their wish to exclude from our discussions all extraneous considerations. Truth is one; all roads which really lead to it will assuredly converge sooner or later: our business is to see that the one we are ourselves concerned with is properly laid out and metalled.

Upon this matter I am glad to be able to fortify myself by two authorities; and first of these I will place an utterance of Archbishop Whately, which may be found in the second volume of his Life, pp. 56–68, and appears to have been uttered by him, æt. 57, an. 1844. "A person possessing real faith will be fully convinced that whatever suppressed physical fact appears to militate against his religion will be proved by physical investigation either to be unreal or else reconcilable with his religion. If I were to found a church, one of my articles would be that it is not allowable to bring forward Scripture or any religious considerations at all to prove or disprove any physical theory or any but religious and moral considerations." My second quotation shall be taken from the great work of one of the first, as I apprehend, of living theologians, John Macleod Campbell, 'The Nature of the Atonement,' pp. xxxii, xxxiii, Introd., and it runs thus:—There are "other minds whose habits of pure scientific investigation are to them a temptation to approach the claim of the kingdom of God on our faith by a wrong path, causing them to ask for a kind of evidence not proper to the subject, and so hindering their

weighing fairly what belongs to it. No scientific study of the phenomena which imply a reign of law could ever have issued in the discovery of the kingdom of God. But neither can it issue in any discovery which contradicts the existence of that kingdom; nor can any mind in the light of the kingdom of God hesitate to conclude that if such seeming contradictions arise there is implied the presence of error either as to facts or as to conclusions from the facts." These are valuable words and weighty testimonies. But in a matter of this importance one must not forbear to point out what may seem to be wanting even in the dicta of such men as the two I have quoted. Neither of them have allowed the possibility of error attaching itself to the utterances of more than one of the two parties in such issues as those contemplated. Neither appears to have thought of the cases in which religious men, if not theologians, have brought woe on the world because of the offences they have with ill-considered enunciations created. And whilst fully sympathizing with all that the Archbishop and Mr. Campbell have said, I must say that they appear to me to have left something unsaid; and this something may be wrapped up in the caution that there may be faults on both sides. But at any rate this Section cannot be considered a fit place for the correction of errors save of the physical kind; and all other considerations are for this week and in this place extraneous. In some other week or in some other place it will be, if it has not already been, our duty to give them our best attention.

To come, now, to the kind of considerations which are the proper business of Section D: let me say that for the discussion of Spontaneous Generation very refined means of observation, and, besides these, very refined means of experimentation are necessary. And I shall act in the spirit of the advice I have already alluded to as given to the world by one of her greatest teachers, if I put before you a simple but a yet undecided question for the solution of which analogous means of a far less delicate character would appear to be, but as yet have not proved themselves to be, sufficient. Thus shall we come to see very plainly some of the bearings, and a few of the difficulties, of the more difficult of the two questions. What an uneducated person might acquiesce in hearing spoken of as spontaneous generation, takes place very constantly under our very eyes, when a plot of ground which has for many years, or even generations, been devoted to carrying some particular vegetable growth, whether grass or trees, has that particular growth removed from it. When such a clearing is effected, we often see a rich or even a rank vegetation of a kind previously not growing on the spot spring up upon it. The like phenomenon is often to be noted on other surfaces newly exposed, as in railway-cuttings and other escarpments, and along the beds of canals or streams, which are laid bare by the turning of the water out of its channel. Fumitory, rocket, knotgrass or cowgrass (*Polygonum aviculare*), and other such weeds, must often have been noted by every one of us here in England as coming into and occupying such recently disturbed territories in force; whilst in America the destruction of a forest of one kind of wood, such as the oak or the chestnut, has often been observed to be followed by an upgrowth of young forest trees of quite another kind, such as the white pine—albeit no such tree had been seen for generations growing near enough to the spot to make the transport of its seeds to the spot seem a likely thing. In one case referred to by Mr. Marsh, 'Man and Nature,' p. 289, the hickory, *Carya porcina*, a kind of walnut, was remarked as succeeding a displaced and destroyed plantation of the white pine. Now the advocates of spontaneous generation must not suspect me of hinting that there is any question, except in the minds of the grossly ignorant, of the operation of any such agency as spontaneous generation here; no one would suggest that the seeds of the *Polygonum aviculare*, to say nothing of those of the hickory, were produced spontaneously; but what I do say is, that the question of how those seeds came there is just the very analogue of the one which they and their opponents have to deal with. And it is not definitely settled at this very moment. Let us glance at the instructive historical parallel it offers. For the very gross and palpable facts of which I have just spoken there are two explanations offered in works of considerable authority. The one which has perhaps the greatest currency and commands the largest amount of acceptance is that which, in the words of De Candolle, regards *la couche de terre végétale d'un pays comme un magasin de graines*, and sup-

poses that in hot summers and autumns, such as the present, the fissures in the ground, which have proved so fatal this year to the young partridges, swallow up a multitude of seeds, which are restored again to life when the deep strata into which they are thus introduced, and in which they are sealed up as the chasms close up, come in any way to be laid open to the unimpeded action of the sun and moisture. Squirrels, again, and some birds resembling herein the rodent mammalia, bury seeds and forget to dig them up again; and it is supposed that they may bury them so deep as to be protected from the two physical agencies just mentioned. Now germination cannot take place in the absence of oxygen; and I would add that well-sinkers know to their cost how often the superficial strata of the earth are surcharged with carbonic acid. The rival explanation and the less popular (I do not say the less scientific) looks to the agency of transportation as occurring constantly, and sufficing to explain the facts. By accepting this explanation, we save ourselves from running counter to certain experiments, some of which were carried out, if I mistake not, under the auspices of this Section (see Brit. Assoc. Reports), and which appear to curtail considerably the time during which seeds retain their vitality, and to multiply considerably the number of conditions which must be in force to allow of such retention for periods far shorter than those which have to be accounted for. A better instance of the expediency of checking the interpretations based merely upon observations, however accurately made, by putting into action experiments, cannot be furnished than by recording the fact put on record by Mr. Bentham, when discussing this question in his last year's address to the Linnean Society.

"Hitherto direct observation has, as far as I am aware, only produced negative results, of which a strong instance has been communicated to me by Dr. Hooker. In deepening the lake in Kew Gardens they uncovered the bed of an old piece of water, upon which there came up a plentiful crop of Typha, a plant not observed in the immediate vicinity; and it was therefore concluded that the seed must have been in the soil. To try the question, Dr. Hooker had six Ward's cases filled with some of the soil remaining uncovered close to that which had produced the Typha, and carefully watched; but not a single Typha came up in any one of them." (Note in President's Address, May 24th, 1869, p. lxxii of Linnean Society's Proceedings.)

To this I would add that experiments with a positive result, and that positive result in favour of the second hypothesis, if hypothesis it can be called, are being constantly tried in our colonies for us, and on a large scale. I had taken and written here of the *Polygonum aviculare*, the "knot" or "cowgrass"—having learnt, on the authority of Dr. Hooker and Mr. Travers (see Natural-History Review, January 1864, p. 124, Oct. 1864, p. 619), that it abounds in New Zealand, along the roadside, just as it does in England—as a glaring instance, and one which would illustrate the real value of the second explanation even to an unscientific man and to an unassisted eye. But on Saturday last I received by post one of those evidences which make an Englishman proud in thinking that whithersoever ships can float thither shall the English language, English manners, and English science be carried, in the shape of the second volume of the Transactions of the New-Zealand Institute, full, like the first, from the beginning to its last page with thoroughly good matter. In that volume, having looked at the table of its contents, I turned to a paper by Mr. T. Kirk on the Naturalized Plants of New Zealand, and in this, at p. 142, I find that Mr. T. Kirk prefers to regard the *Polygonum aviculare* of New Zealand as indigenous in New Zealand. Hence that illustration which would have been a good one falls from my hands. And I must in fairness add, that because one agency is proved to be a *vera causa*, it is not thereby proved that no other can by any possibility be competent simultaneously to produce the same effect, whatever the Schoolmen with the law of Parsimony ringing in their ears may have said to the contrary. I have dwelt upon this subject at this length with the purpose of showing how much difficulty may beset the settlement of even a comparatively simple question which involves only the use of the unassisted eye, or at most of a simple lens. The *à fortiori* argument I leave you to draw for yourselves, with the simple remark that the question of spontaneous generation is now at least one to be decided by the microscope, and by the employment of its highest powers in alliance with other apparatus of all but equal complexity.

We come, in the second place, to say a word as to the extent of the influence which organic and living particles, of microscopic minuteness but solid for all that, have been supposed, and in some instances at least have been proved, to exercise upon the genesis and genesiology of disease, and so upon the fortunes of our race, and our means for bettering our condition, and that of our fellows. I need not refer to Dr. Sanderson's valuable Report (just published in the Privy Council's Medical Officer's Blue Book, Twelfth Report, 1870, p. 229) upon those contagion particles which he proposes to call by the convenient name, slightly modified from one invented by Professor Béchamp, of "Microzymes;" for Dr. Sanderson is here to refer to the matter for himself and for us; and when this meeting is over we shall all do well to lay to heart what he may tell us here and now, and, besides this, to study his already printed views upon the matter. It may be perhaps my business to remind you that these views, so far as they are identical with Professor Halliers's as to the importance of those most minute of living organisms, the micrococcus of his nomenclature, the microzymes of Mr. Simon's Blue Book, were passed in review as to their botanical correctness by a predecessor of mine in this honourable office—namely, by the Rev. J. M. Berkeley, at the Meeting held two years ago at Norwich; and that some of the bearings of the theory and of the facts, howsoever interpreted, upon the Theory of Evolution, were touched upon by Dr. Child in his interesting volume of 'Physiological Essays,' p. 148, published last year. It would not perhaps be exactly my business to express my dissent from any of these results or views put forward by any of these investigators I have mentioned; but I wish to point out to the general public that none of these inquirers would affirm that the agencies shown by them to be potent in the causation of *certain* diseases were types and models of the agencies which are, did we but know it, could we but detect them, potent in the causation of *all* diseases. Many diseases, though, possibly enough, not the majority of the strictly infectious diseases, are due to material agents quite distinct in nature from any self-multiplying bodies, cytoid or colloid. To say nothing of the effects of certain elements (and elements, it will be recollected, in their singleness and simple atomicity, have, as the world happens to be constituted and governed, never been honoured with the office of harbouring life) which when volatized, as mercury, arsenic, and phosphorus may be, or indeed which, when simply dissolved, may be most ruinous to life, there are, I make no doubt, animal poisons produced in and by animals, and acting upon animal bodies, which are neither organized nor living, neither cytoid nor colloid. Dr. Charlton Bastian is not likely to underrate the importance of such agents, howsoever produced, in the economy, or rather in the waste, of Nature; yet from his very careful record of his own very closely observed and personal experience we can gather that he would not demur to conceding that non-vitalized, however much animalized, exhalations may be only too powerful in producing attacks, and those sudden and violent and fever-like attacks, of disease. Dr. Bastian tells us (Phil. Trans. for 1866, vol. 196, pt. ii. pp. 583, 584) that whensoever he employed himself in the dissection of a particular nematoid worm, the *Ascaris megalocephala*, he found occasion to observe, and that in himself, and very closely, the genesiology of a spasmodic and catarrhal affection, not unlike hay-fever as it seems to me, but under circumstances which appear to preclude the possibility of any living organisms being the cause of it as they have been supposed, and by no less an authority than Helmholtz, to be of the malady just mentioned. For in Dr. Bastian's case this affection was produced, not only when the *Ascaris megalocephala* was dissected when fresh, but "after it had been preserved *in methylated spirit for two years, and even then macerated in a solution of chloride of lime for several hours before it was submitted to examination.*" Could any microzyme or megalozyme have survived such an amount of antizymotic treatment—such a pickling as this? This is not exactly a medical association, and I have entered upon this discussion not altogether without a wish to show how subjects of apparently the most purely scientific and special interest, as Mycology and Helminthology (the natural history, that is to say, and the morphology of the lowest plants and of the lowest Vermes), may, when we least expect it, come or be brought to bear upon matters of the most immediate and pressing practical importance. And in this spirit I must say a word upon the way in which the pathology of snake-bites bears upon the matters

I have been speaking of, and the extent of the debt which practical men owe to such societies as our Ray Society, and to such publications as their colossal volume on the snakes of India, in which Dr. Günther's views as to the real history of the striking and terrible yet instructive phenomena alluded to are combined ('Reptiles of British India,' Ray Society, 1864, p. 167). That the snake-poison is an animal poison is plain enough; that it is fatal to men and animals everybody knows; but I rather think that these two facts relative to it are not equally notorious, rich in light though they be, viz. that the potency of this particular animal poison varies in direct ratio to the quantity imbibed or infused, just as though it were so much alcohol, or so much alcoholic tincture of musk or cantharides; or secondly, that its potency varies in direct ratio to another varying standard, viz. the size of the animal producing it. Now the vaccine matter from the arm of a child is as potent as the vaccine matter from the arm of any giant would be; and whether a grain or a gramme of it be used will make no difference, so long as it be used rightly. There is a contrast, indeed, between the *modus operandi* of these two animal poisons. I would add that in the 'Edinburgh Monthly Medical Journal' for the present month there is a very valuable paper, one of a series of papers, indeed, of the like character, by Dr. Fayrer, where at page 247, among much of anatomical and other interest, I find the following important statement:—"This poison may be diluted with water, or even ammonia or alcohol, without destroying its deadly properties. It may be kept for months or years, dried between slips of glass, and still retain its virulence. It is capable of absorption through delicate membranes, and therefore it cannot be applied to any mucous surfaces, though no doubt its virulence is much diminished by endosmosis*. It appears to act by a catalytic form; that is, it kills by some occult influence on the nerve centres." There is such a thing as an ignorance which is wiser than knowledge, *for the time*, of course, only; such an ignorance is wisely confessed to in these words of Dr. Fayrer's. An explanation may be true for some, yet not thereby necessarily for all, the facts within even a single sphere of study; even a true explanation may have but a very limited application, as a tangent cannot touch a circle at more than a single point. The memoirs published in our own reports by Dr. R. W. Richardson, on the action of the nitrites, and those published by Dr. A. Crum Brown and Dr. Fraser, there and elsewhere, on the connexion between chemical constitution and physiological action, deserve especial study as bearing on the other side of this discussion; whilst Prof. Lister's papers show how the reference of certain diseases to vitalistic agencies may become of most vital importance in practice. There exists, as is well known, a tendency to resolve all physiological into physico-chemical phenomena: undoubtedly many have been, and some more may still remain to be, so resolved; but the public may rest assured that in the kingdom of Biology no desire for a rectification of frontiers will ever be called out by any such attempts at, or successes in the way of, encroachment; and that where physics and chemistry can show that physico-chemical agencies are sufficient to account for the phenomena, there their claim upon the territory will be acceded to, as in the cases we have been glancing at; and where such claims cannot be established and fail to come up to the quantitative requirements of strict science, as in the cases of continuous and of discontinuous development or self-multiplication of a contagious germ, and in some others, they will be disallowed.

Pathology has of late made a return to Physiology for much service she has received, and this in the following directions. Dr. W. Ogle has thrown much light on the physiology of the cervical sympathetic nervous system by his record of a pathological history to be found in the recently issued volume (vol. lii.) of the 'Medico-Chirurgical Transactions.' The rough and cruel experimentation of war has had its vivisections utilized for the elucidation of the physiology of nerves, and especially of their trophic function, in the valuable volume issued by the American Sanitary Commission, under the editorship of Dr. Austin Flint. Dr. Broadbent has done something towards elucidating the question of the localization

* Diapedesis may account for what virulence remains, and the poison may therefore possibly be a cytoid.

of functions in particular parts of the cerebral convolutions, which was so extensively and so very exhaustively discussed at Norwich, by his paper in our most useful and comprehensive 'Cambridge and Edinburgh Journal of Anatomy and Physiology,' May 1870, "On the Cerebral Convolutions of a Deaf and Dumb Woman."

I take this opportunity of mentioning two valuable papers on the very practical question of the influence of the vagus upon the heart's action. One of these is a German paper by a gentleman who is a zoologist and comparative anatomist as well as a physiologist, Dr. A. B. Meyer; "Das Hemmungsnerven-System des Herzens" is the title of his memoir, a separate publication as I think: the other is an abstract of a paper [I have not seen the paper published *in extenso* as yet] by Dr. Rutherford, "On the Influence of the Vagus upon the Vascular System," published in the journal just referred to. Especially do I think Dr. Rutherford's view as to the vagus acting centrifugally as regards the stomach, and carrying stimulus, not thither but thence, to the medulla oblongata, which stimulus is then radiated downwards by a route formed distally by the splanchnic nerve, so as to produce inhibitory vascular dilatation in the neighbourhood of the peptic cells, as worthy of attention*.

A considerable number of the papers which will be read before this Section, indeed a considerable part of the Section itself, will be devoted to the Natural History of Man. Nothing, I apprehend, is more distinctive of the present phase of that "proper study of mankind" than the now accomplished formation of a close alliance between the students of archæology strict and proper and the biologist with the express purpose of jointly occupying and cultivating that vast territory. Literature and art and the products of the arts furnish each their data to the ethnologist and anthropologist in addition to those which it is the business of the anatomist, the physiologist, the palæontologist, and the physical geographer to be acquainted with; nor can any conclusion attained to by following up any single one of those lines of investigation be considered as definitely absolved from the condition of the provisional until it has been shown that it can never be put into opposition with any conclusion legitimately arrived at along any other of the routes specified. In political alliances the shortcomings of one party necessarily hamper and check the advance of the other; a failure in the means or in the perseverance of one party may bring the joint enterprise to a premature close; mutual forbearance, not to dwell longer upon extreme cases, may finally be as effectual in slackening progress as even mutual jealousies. No such disadvantages attach themselves to the alliance of literature with science, as the German 'Archiv für Anthropologie,' issued to the world under the joint management of Ecker the biologist and Lindenschmit the antiquarian, will show any one who consults its pages, replete with many-sided but not superficial, multifarious but never inaccurate, information.

The antiquary is a little prone, if he will allow me to say so, when left alone, to make himself but a connoisseur; the historian, whilst striving to avoid the Scylla of judicial dulness, slides into the Charybdis of political partisanship; and the biologist not rarely shows himself a little cold to matters of moral and social interest whilst absorbed in the enthusiasm of speciality. The combination of minds varying in bent is found efficacious in correcting these aberrations; and by this combination we obtain that white and dry light which is so comforting to the eye of the truth-loving student, to say nothing as to its being so much stronger than the coloured rays which the work of one isolated student may sometimes have cast upon it from the work of another. It would be invidious to speculate, and I have forborne from suggesting whether the literary contingent in the conquering though composite army has learnt more from observation of the methods and evolutions of the scientific contingent, or the scientific more from the observation of the literary; it is, however, neither invidious nor superfluous to congratulate the general public upon the necessity which these, like other allies, have been re-

* Since writing as above I have seen, but have not read, a paper by Dr. Coats in Ludwig's "Arbeiten aus der physiologischen Anstalt zu Leipzig" for the present year, which would seem to treat of this subject. The Würtzburg Physiological Laboratory Reports for 1867–68 contain, as is well known, a series of papers upon it.

duced to, of adopting one common code of signals, and discarding the exclusive use of their several and distinctive technicalities. Subjects of a universal interest have thus come to be treated, and that by persons now amongst us, in a language universally "understanded of the people." I have been careful to include the palæontologist amongst the scientific specialists whose peculiar researches have cast a helpful and indeed an indispensable light upon the history of the fates and fortunes of our species. But it is not organic science only which anthropology impresses into its service; and it would be the sheerest ingratitude to forget the help which the mineralogist gives us in assigning the source whence the jade celt has come or could come, or to omit an acknowledgment of the toil of the analytical chemist, who has given the percentage of the tin in the bronze celt, or in the so-called "leaden" and therefore Roman coffin.

I am very well aware that many persons who have honoured me by listening to the last few sentences have been thinking that it is at least premature to attempt to harmonize the two classes of evidence in question; and that the best advice that can be given to the two set of workers severally is, that they should work independently of each other. Craniography is said, and by irrefragable authority, to be a most deceptive guide; works and articles on ethnology tell us stories of skulls being labelled, even in museums of the first order of merit, with such Janus-like tickets as "Etruscan Tyrol *or* Inca Peruvian;" and one of the most celebrated anthropotomists of the day has been so impressed with the fact that Peruvian as well as Javanese and Ethiopian skulls may be found on living shoulders within the precincts of a single German university town, that he has busied himself with forming a pseudo-typical ethnological series from the source and area just indicated. Great has been the scandal thence accruing to craniography, and the collector of skulls has thence come to be looked upon as a dilettante with singular ghoul-like propensities, which are pardonable only because they relate only to savage races of modern days, or to cemeteries several hundred years old, but which are not to be regarded as being seriously scientific. Now to me the existence of such a way of estimating such a work appears to argue a sad amount of ignorance of the laws of the logic of practical life, or, indeed, of the chapters on "approximate generalizations," which any man, however unpractical, can read in a treatise on logic. A man's features and physiognomy are instinctively and intuitively, or, if you prefer so to put it, as a result of the accumulated social experiences of generations of men, taken as a more or less valuable and trustworthy indication of his character; were this not so, photographers would not, as I apprehend, and hope they do, make fortunes; yet the face is at least as often fallacious as an index of the mind as the skull is fallacious as an index of race. The story of the misconception by a physiognomist of the character of Socrates is familiar to us, as I think, from Lemprière's Dictionary; and it may serve to parallel the story which Blumenbach and Tilesius tell us of the exact correspondence of the proportions of a skull from Nukahiva with those of the Apollo Belvidere. The living faces in a gaol, again, to put the same argument upon other grounds, are as dangerous to judge from as are the skulls in a museum; yet every detective is something like a professor of physiognomy, and most of them could write a good commentary on Lavater. The true state of the case may, perhaps, be represented thus:—A person who has had a large series of crania through his hands, of the authenticity of which, as to place and data, he has himself had evidence, might express himself, perhaps, somewhat to the following effect if he were asked whether he had gathered from his examination of such a series any confidence as to his power of referring to, or excluding from, any such series any skull which he had not seen before. He might say, "the human, like other highly organized types of life, admits of great variety; aberrant forms arise, even in our own species, under conditions of the greatest uniformity possible to humanity: amongst savages great variety exists (see Bates, 'Naturalist on the Amazons,' ii. p. 129), even though they all of them may live the same 'dull grey life' and die the same 'apathetic end;' and consequently it may never, except in the case of Australian or Esquimaux, and perhaps a few other crania, be quite safe to pledge one's self as to the nationality of a single skull. Still there is such a thing as craniographical type; and if half a dozen sets, consisting of ten crania apiece, each assortment having been taken from the ceme-

teries of some well-marked nationality, were set before me, I would venture to say, after consultation and comparison, that it might be possible to show that unassisted cranioscopy, if not invariably right, even under such favourable circumstances, was nevertheless not wrong in a very large number of cases." If it is true on the one hand that *in generalibus latet error*, it is true on the other that security is given us by the examination of large numbers for the accuracy and reliability of our averages, a principle which Gratiolet informs us is thoroughly recognized in Chinese metaphysics, and which he has formulated in the following words:—"L'invariabilité dans le milieu s'applique à tout. La verité n'est point dans un seul fait mais dans tous les faits; elle est dans les moyennes, c'est-à-dire dans une suite d'abstractions formulées après le plus grand nombre d'observations possibles." (Mémoire sur les Plis cérébraux, p. 93). The natural-history sciences do not usually admit of the strictness which says that an exception, so far from proving a rule, proves it to be a bad one; rather are we wise in saying that in them at least the universality of assertion is in an inverse ratio to that of knowledge, and that the sweeping statements dear, as Aristotle long ago remarked (Rhetoric, ii. 21. 9 & 10; ii. 22. 1), to a class which he contrasts with the educated, are abhorrent to the mind of organic nature. It is true enough, as is sometimes said, that when opinions and assertions are always hedged in by qualifications, the style becomes embarrassed, and the meaning occasionally hard to be understood; but this difficulty is one which lies in the very nature of the case, and the real excellence of style does not consist in its lulling the attention and relieving the memory by throwing an alliterative ring on to the ear, but in the furnishing a closely fitting dress to thought, and an accurate representation of actual fact.

If we are told that the attempt to harmonize the results, not merely of cranioscopy, but of any and all natural-science investigation, with the results of literary and linguistic research, is needless and even futile, this is simply equivalent to saying that one or other of these methods is worthless. For as Truth is one, if two routes purporting both alike to lead to it do not sooner or later converge and harmonize, this can only be because one or other of them fails to impinge upon the goal. It is true that by certain lines of investigation light is thrown upon a problem only at a single point, and that all further prosecution of investigation along that line will but lead us off at a tangent. Still the throwing of even a single ray upon a dark surface is an achievement with a value of its own; and it is a cardinal rule in our sciences never to ignore the existence of seemingly contradictory data, in whatsoever quarter they may show themselves. For what would be said of an investigator of a subject such as physical geography, who should declare that he would pay no attention except to a single set of data, when he was discussing whether a particular archipelago had been formed by upheaval, or should be held to be the fragments and remnants of a disrupted continent; and that if geological evidence was in crying discord with his interpretation of the facts of the distribution of species, it was not his business to reconcile them. He would be held to have neglected his business, as you may see by a reference to Mr. Bentham's Address to the Linnean Society, May 24, 1869 (Linn. Soc. Proc. for 1869, p. xcii *).

The argument from identity of customs and practices to identity of race is liable to much the same objections and to much the same fallacies as is the argument from identity of cranial conformation. The case may be found admirably stated in Mr. Tylor's work on the 'Early History of Mankind,' p. 276, ed. 2; and I may say that the means of bringing the problem home to one's self may be found by a visit to any collection of flint implements. In such a collection, as Mr. Tylor has pointed out, p. 205, we are very soon impressed with the marked uniformity which characterizes these implements, whether modern or thousands of years old, whether found on this side of the world or the other. For example, a flint arrow-head

* The following references to passages of the kind referred to above as to the untrustworthiness of craniographical evidence may be useful:—Geographisches Jahrbuch, 1866, p. 481. Hyrtl, Topograph. Anatomie, i. p. 13. Henle, System. Anat. i. 198. Krause, i. 2, p. 251. Archiv für Anthropologie, Holder, *ibid.* ii. 1, p. 60. See also His and Rütimeyer, and Ecker in their systematic works severally, the 'Crania Helvetica' and the 'Crania Germaniæ meridionalis.'

which came into my hands a short time back, through the kindness of Lord Antrim, after having done duty in these iron times as a charm at the bottom of a water-tub for cattle in Ireland, was pointed out or at to me by a very distinguished Canadian naturalist, who was visiting Oxford the other day, as being closely similar to the weapons manufactured by the Canadian Indians. Now after such an experience one may do well to ask in Mr. Tylor's words ('Early History,' p. 206) :—

"How, then, is this remarkable uniformity to be explained? The principle that man does the same thing under the same circumstances will account for much, but it is very doubtful whether it can be stretched far enough to account for even the greater proportion of the facts in question. The other side of the argument is, of course, that resemblance is due to connexion, and the truth is made up of the two, though in what proportions we do not know. It may be that, though the problem is too obscure to be worked out alone, the uniformity of development in different regions of the Stone age may some day be successfully brought in with other lines of argument, based on deep-lying agreements in culture which tend to centralize the early history of races of very unlike appearances, and living in widely distant ages and countries."

If the psychological identity of our species may explain the identity of certain customs, its physiological identity may explain certain others. Some of this latter class are of a curious kind, and relate not to matters of social or family, but to matters of purely personal and individual interest, concerning as they do the sensibility, and with it all the other functions of the living body. Such customs are the wearing of labrets or lip-rings, nose-rings, and, if I may add it without offence, of certain other rings inserted in the wide region supplied by the fifth or trifacial nerve*. A physiological explanation may lie at the base of these practices, which appear to put at the disposal of the persons who adopt them a perennial means for setting up an irritation, whence reflex consequences in the course of reflex nutrition and reflex secretion, as of gastric juice, may flow. A curious book was written, or at least published, on the subject of these practices, and others akin to them, in 1653, by Dr. John Bulwer, a benevolent doctor, who paid attention to the care of the deaf and dumb previously, I think it is stated, to Dr. Wallis, and who consequently, with proper pride, if this precedence really belongs to him, signs himself "J. B. cognomento Chirosophus." The title of the book is "Anthropometamorphosis; Man Transformed, or the Artificial Changeling." I was made acquainted with its existence by my friend Mr. Tomlinson, of Worcester College, from the library of which Society I procured a copy for consultation: the book is not rare I think, but I think it is little known; it contains much that is curious, and it is, inasmuch as it was written more than 200 years ago, ὅτ' ἀκήρατος ἦν ἔτι λειμών, from some, though not from all points of view, the more valuable. It is, I apprehend, to some of these customs, as well as to others, that Zimmermann (not the author of the work on Solitude, but Zimmermann the zoologist) alludes in a rather amusing passage, which may be found in the third volume of his larger work on the Distribution of Species and on Zoology (see p. 257). I speak of the passage as amusing; it is more than that, or I would not quote it; indeed you will not see that it is particularly amusing unless I tell you that volumes ii. and iii. are of date 1783, and are dedicated to his own father, whilst volume i., of date 1778, is dedicated to "His Most Serene Highness and Lord, Ferdinand Duke of Brunswick, my Most Gracious Lord." Its quality of amusingness depends upon these dates, and the speculations they set us to make as to how the Serene Duke, his "Most Gracious Lord," had offended the man of science in the interval between 1778 and 1783. It runs thus:—"If you argue from similarity of customs and ceremonies to identity of origin of two tribes under comparison, you must first show that these customs are not such as would naturally tend to the amelioration of the conditions of the inhabitants in the two countries under consideration, and would probably therefore, or can naturally, suggest themselves to each of the races in question. Or there may be customs founded on innate folly and stupidity, and thus, for your argument to be valid, you must show that of two peoples widely separated, each cannot by any chance come into its own country to adopt the like foolish and stupid customs. For whilst two wise heads are to make out, each independently of the other and

* See 'Medicine in Modern Times,' p. 57.

contemporaneously, a wise discovery or invention, it is much more likely on the calculation of chances, and considering the much greater number of fools and blockheads ('Thoren und Dummköpfen'), that in two countries widely apart closely similar follies should be simultaneously invented. And then, if the inventing fool happens to be a man of influence and consideration, *which is, by the way, an exceedingly frequent coincidence*, both the nations are likely to adopt the same foolish practice, and the historian and antiquarian, after the lapse of some centuries, is likely to draw from this coincidence the conclusion that the two nations both sprang from the same stock." Judge and speculate for yourselves how the spirit which breathes in this passage was excited, but note its scientific value too. We must not forget that it is possible, in thought, at least, to dissociate the psychological unity of man from his specific identity even; and that, as regards identity of race, it is only reasonable to expect that when similar needs are pressing, similar means for meeting them are not unlikely to be devised independently by members of two tribes who have for ages been separated from their original stocks. The question to be asked is, does the contrivance about which we are speculating combine, or does it not combine in itself so large a number of converging adaptations as to render it upon the calculation of chances unlikely that it should have been independently invented? Yet this very obvious principle has been neglected, or Lindenschmit would not have found it necessary to say that, by laying too much stress upon certain points of national identity in the stones used for the formation of cromlechs or dolmens, the Hünenvolk might be made out to have chosen to settle only in those parts of Germany where erratic blocks of granite or other such large stones could be found! (Archiv für Anthropologie, iii. p. 115, 1868).

Sir John Lubbock's recently published work on 'The Origin of Civilization' may, I anticipate, cause the history and genealogy of manners and customs to enter largely into the composition of our lists of papers. There is no need for me, as the author of the book is here himself to speak, as announced, for himself, to occupy your time in recommending his work; but I may be allowed to say that the utility of such pursuits as those which Sir John Lubbock's book treats of receives some little illustration from the fact that, as we learn from him and from Mr. Tylor, the human mind blunders and errs and deceives itself in these subjects in just the same way as it does in the kindred, though more immediately arising, pressing, and important matters of social and political life. In these latter spheres of observation we are apt occasionally to mistake one of those intermittent reactions of opinion, produced as eddies are produced in a river by the deposit of sand and mud at angles in its onward course, for a deliberate giving up of the principles upon which all previous progress has been dependent. The straws which float upon the surface of a backwater may be taken as proofs that the river is about to flow upwards, and a feeble oarsman in a light boat may be deceived for some moments by the backward drifting of his small craft. Now an analogous blunder is often made in matters of purely historical interest; and we may do well to learn from the experience thus cheaply earned. "The history of the human race has," says Sir J. Lubbock, p. 322, *l. c.*, "I feel satisfied, on the whole been one of progress: I do not of course mean to say that every race is necessarily advancing; on the contrary, most of the lower are almost stationary:" but Sir John regards these as exceptional instances, and points out that if the past history of man had been one of deterioration, we have but a groundless expectation of future improvement; whilst on the other, if the past has been one of progress, we may fairly hope that the future will be so also.

Mr. Tylor's words are equally to the purpose, though, as forming the end of a chapter merely and not the end of a book, they are less enthusiastic in tone (p. 193, Tylor, 'Early History of Mankind'). They run thus:—

"To judge from experience, it would seem that the world, when it has once got a firmer grasp of new knowledge or a new art, is very loath to lose it altogether, especially when it relates to matters important to man in general, for the conduct of his daily life, and the satisfaction of his daily wants, things that come home to men's 'business and bosoms.' An inspection of the geographical distribution of art and knowledge among mankind seems to give some grounds for the belief that the history of the lower races, as of the higher, is not the history of a course

of degeneration or even of equal oscillations to and fro, but of a movement which, in spite of frequent stops and relapses, has on the whole been forward; that there has been from age to age a growth in man's power over nature, which no degrading influences have been able permanently to check."

I must not trespass into the province of the botanist, but I should be glad to say that no easier method of learning how the natural-history sciences can be made to bear upon the history of man, as a whole, can be devised than that furnished by the perusal of such memoirs as those of Unger's upon the plants used for food by man. The very heading and title of the paper I am specially referring to appears to me to have an ambiguity about it which, in itself, is not a little instructive. In that title, "Botanische Streifzüge auf dem Gebiete der Cultur-Geschichte," the latter word may be taken, I imagine, etymologically at least, to refer either to culture proper, or to floriculture, or to agriculture. At any rate, the paper itself may be read in the Sitzungsberichte of the Vienna Academy for 1859; it has, I suppose, superseded the interesting chapters in Link's 'Urwelt und Alterthum,' of date 1821; and it is not unlikely, I apprehend, to be itself, in its turn, superseded also.

Coming, in the third place, to Zoology, I suppose I shall be justified in saying that the largest issue which has been raised in the current year, an issue for the examination of the data for deciding which the two months of July and August which are just past may have furnished persons now present with opportunities, is the question of the kinship of the Ascidians to the Vertebrata. There is or was nothing better established till the appearance of Kowalewsky's paper, now about four years ago, than the existence of a wide gulf between the two great divisions of the animal kingdom, the Vertebrata and the Invertebrata: nothing could be more revolutionary than the views which would obviously rise out of his facts; and within the present year these facts have been abundantly confirmed by Prof. Kupfer, whose very clearly written and beautifully illustrated paper has just appeared in the current number of Schultze's 'Archiv für microscopische Anatomie.' Kupfer's researches have been carried on upon *Ascidia canina*; but they more than confirm the accuracy of what Kowalewsky had stated to take place in *Ascidia mammillata*, and which may be summed up briefly thus:—In the larval Ascidian we have in its caudal appendages an axis skeleton clearly analogous, if not essentially homologous, to the chorda dorsalis of the vertebrate embryo, as consisting, like it, of rows of internally placed cells, and giving insertion by its sheath to muscles. We have further the nervous system and the digestive taking up in such embryos much the same positions relatively to each other, and to this molluscan chorda dorsalis, that are taken up by the confessedly homologous system in the Vertebrata; we have the nervous system originating in the same fashion and closing up like the vertebrate myelencephalon out of the early form of a lamellar furrow into that of a closed tube; we have, finally, the respiratory and digestive inlets holding the vertebrate relationship of continuity with, instead of the invertebrate of dislocation and separation from, each other. Such are the facts; but I am not convinced that they will bear the interpretation that has been put upon them; though I must say the possession of this chorda dorsalis by the active locomotor larva of the Ascidian which one day settles down into such immobility lends not a little probability to Mr. Herbert Spencer's view of the genesis of the segmented vertebral column in animals undoubtedly vertebrate. But on this view I should not be inconsistent with myself, inasmuch as, to waive other considerations, the chorda dorsalis in each case would be considered as an adaptive or teleological modification, not a sign of morphological kinship*. Much perplexity may or must arise here; and whilst entertaining these views, I felt myself bound to examine myself strictly to find whether in not taking them up, I might not be giving way to that reactionary reluctance to accept new ideas which advancing years so frequently bring with them; but a recent paper, by Lacaze-Duthiers, published in the 'Comptes Rendus' for May 30, 1870, and translated in the 'Annals and Magazine of Natural History' for July 1870, would justify me, I think, in calling that reluc-

* See, however, Mr. Herbert Spencer's Appendix D to his principles of Biology, pt. iv. chap. xvi. This appendix was printed in 1865, but not published till December 1869. I had not seen it when I wrote as above.

tance by another name. For in that paper the renowned malacologist just mentioned has brought to light the fact that there is another sessile and solitary Ascidian, the *Molgula tubulosa*, which goes through no such tadpole-like stage as had been supposed to be gone through by all Ascidians except the Salpæ, which is never active and never puts out the activity which is so remarkable in the other Ascidians, but settles down and remains sedentary immediately after it is set free from the egg-capsula, neither enjoying a Wanderjahr *nor possessing a chorda dorsalis.* We are not surprised after this that M. Lacaze-Duthiers observes that "although embryology may and must furnish valuable information by itself, it may also, in some cases, lead us into the gravest errors." Mr. Hancock, of Newcastle-upon-Tyne, has sent us a paper upon this subject, which will be read duly and duly noted by us.

Leaving Malacology, which has not in the United Kingdom obtained the same hold as yet upon the public mind that it has on the Continent, where, like Entomology, there and here, it has a periodical or two devoted to the recording of the discoveries of its votaries, I have much pleasure in directing attention to two short papers by Siebold in the 'Zeitschrift für wissenschaftliche Zoologie' (xx. 2, 1870), on parthenogenesis in *Polistes gallica* v. *diadema*, and on pædogenesis in the *Strepsiptera.* In each of these short papers Siebold informs us that adequate room and time could not be given them in the Innsbruck meeting held just a year ago, or in the report of the meeting. It is to me a matter of difficulty to think what there could have been of greater value than those papers in a section of Wissenschaftliche Zoologie; it will be to all present a matter of congratulation to learn, from the venerable professor's papers, that he will shortly favour us with a new work on the subject of parthenogenesis. A fresh instance of parthenogenesis in Diptera, viz. in *Chironomus*, has just been put upon record in the St. Petersburg Imperial Academy's Memoirs (xv. 8, January 13, 1870).

The subject of the geographical distribution of the various forms of vegetable and animal life over the surface of the globe, and in the various media, air, earth, water, fresh and salt, whether deep or shallow, has always been, and will always remain, one of the most interesting subsections of biology. It was the contemplation of a simple case of geographical distribution in the Galapagos archipelago which brought the author of the 'Origin of Species' face to face with the problem which the title of his work embodies; and it is impossible that sets of analogous and of more complicated facts (many of which, be it recollected, such as the combination now being effected between our own fauna and flora and those of Australia and New Zealand, are patent to the observations of the least observing) should not, since the appearance of that book, force the serious consideration of the explanation it offers upon the thoughts of all who think at all. The wonders of the deep-sea fauna will, I apprehend, form one, the commensalism of Professor Van Beneden another, subject of discussion, and furnish an opportunity for receiving instruction to all of us. The one set of observations is a striking exemplification of the way in which organisms have become suited to inorganic environments; the other is an all but equally striking exemplification of the way in which organisms can fit and adapt themselves to each other. The current journals have*, as was their duty, made us acquainted with what has been done in both of these directions; and I am happy to say that in the case of the deep-sea explorations, as in that of parthenogenesis and spontaneous generation, a new work, giving a connected and general view of the entire subject, is announced for publication.

One instance of the large proportions of the questions which the facts of geographical distribution bear upon, is furnished to us in the address recently delivered before the Geological Society by its president, who is also our president, and who may have forgotten to refer to his own work (see 'Nature,' No. 24, 1870). Another may be found in the demonstration which Dr. Günther, contrary to our ordinarily taught doctrines, has given us (Zool. Soc. Trans. vol. vi. pt. 7, 1868, p. 307) of the partial identity of the fish-faunas of the Atlantic and Pacific coasts of Central America; many, thirdly, are furnished to us by Mr. Wallace's works *passim.*

It would be superfluous, after introducing even thus hurriedly to your notice so

* See 'Nature,' No. 39, July 28, 1870, and Royal Society's Proceedings, August 1870, for deep-sea explorations, and 'Academy,' September 10, 1870, for commensalism.

large a series of interesting and important subjects as being subjects with which we shall forthwith begin to deal in this Section, to say any thing at length as to the advantages which may reasonably be expected to accrue from the study of Biology. I may put its claims before you in a rough way by saying that I should be rejoiced indeed if, when money comes to be granted by the Association for the following up the various lines of biological research upon which certain of its members are engaged, we could hope to obtain a one hundredth, or I might say a thousandth part of the amount of money which has in the past year been lost to the State and to individuals through ignorance or disregard of biological laws now well established. I need say nothing of the suffering or death which anti-sanitary conditions entail, as surely as, though less palpably and rapidly than, a fire or a battle; and I might, if there were time for it, take my stand simply upon what is measurable by money. This I will not do, as it is less pleasant to speak of what has been lost than of that which has been or may be gained. And of this latter let me speak in a few words, and under two heads—the intellectual and the moral gains accruing from a study of the Natural-History Sciences. As to the intellectual gains, the real psychologist and the true logician know very well that the discourse on method which comes from a man who is an actual investigator is worthy, even though it be but short and packed away in an Introduction or an Appendix, or though it cover but a couple of pages in the middle of a book, like the "Regulæ Philosophandi" of Newton, more than whole columns of the "Sophistical Dialectic" of the ancient Schoolman and his modern followers. "If you wish your son to become a logician," said Johnson, "let him study Chillingworth"—meaning thereby that real vital knowledge of the art and science can arise only out of the practice of reasoning; and as to the value of actual experimentation as a qualification for writing about method, Claude Bernard and Berthelot are, and I trust will long remain, living examples of what Descartes and Pascal, their fellow-countrymen, are illustrious departed examples. (See Janet, 'Revue de deux Mondes,' tome lxii. p. 910, 1866.)

I pass on now to say a word on the working of natural-science studies upon the faculty of attention, the faculty which has very often and very truly been spoken of as forming the connecting-link between the intellectual and the moral elements of our immaterial nature. I am able to illustrate their beneficial working in producing carefulness and in enforcing perseverance, by a story turning upon the use of, or rather upon the need for, a word. Von Baer, now the Nestor of biologists, after a long argumentation (Mém. Acad. Imp. Sci. St. Pétersbourg, 1859, p. 340) of the value which characterizes his argumentations generally, as to the affinities of certain oceanic races, proceeds to consider how it is that certain of his predecessors in that sphere, or, rather, in that hemisphere, as Mr. Wallace has taught us Oceania is very nearly, had so lamentably failed in attaining or coming anywhere near to the truth. This failure is ascribed to something which he calls "Ungenirtheit," a word which you will not find in a German dictionary, the thing itself not being, Von Baer says, German either. I am happy not to be able to find an exact equivalent for this word in any single English vocable; the opposite quality shows itself in facing conscientiously "the drudgery of details, without which drudgery," Dr. Temple tells us (Nine Schools Commission Report, vol. ii. p. 311), "nothing worth doing was ever yet done." Mr. Mill, I would add, speaks to the same effect, and even more appositely, as far as our purpose and our vocations are concerned, in his wise Inaugural Address at St. Andrews, p. 50. For the utter incompatibility of an ἀταλαίπωρος ζήτησις (these two words give a Thucydidean rendering of "*Ungenirtheit*") with the successful investigation of natural problems, I would refer any man of thought, even though he be not a biologist, to a consideration of the way in which problems as simple at first sight as the question of the feeding or non-feeding of the salmon in fresh water (see Dr. McIntosh, Linn. Soc. Proc. vii. p. 148), or that of the agencies whereby certain mollusks and annelids bore their way into wood, clay, or rocks, must be investigated. It is easy to gather from such a consideration how severe are the requirements made by natural-science investigations upon the liveliness and continuousness with which we must keep our faculty of attention at work.

I shall speak of but one of the many purely moral benefits which may be rea-

sonably regarded either as the fruit of a devotion to or as a preliminary to success in natural science. Of this I will speak in the words of Helmholtz, taking those words from a report of them as spoken at the meeting of the German Association for the Advancement of Science, which was held last year at Innsbruck. There Professor Helmholtz, in speaking of the distinctive characteristics of German scientific men, and of their truthfulness in particular, is reported to have used the following words:—"Es hat diesen Vorzug auch wesentlich zu verdanken der *Sittenstrenge* und *der uneigennutzige Begeisterung* welche die Männer der Wissenschaft beherrscht und beseelt hat, und welche sie nicht gekehrt hat an äussere Vortheile und gesellschaftliche Meinungen." These words are, I think, to the effect that the characteristics in question are in reality to be ascribed to the *severe simplicity of manners* and *to the absence of a spirit of self-seeking*, which form the guiding and inspiring principles of their men of science, and prevent them from giving themselves up to the pursuit of mere worldly advantages, and from paying undue homage to the prejudices of society. I think *Sittenstrenge* may be considered as more or less adequately rendered by the words *severe simplicity of manners*; at any rate, as things are known by their opposites, let me say that it is the exact contradictory of that "*profound idleness and luxuriousness*" which, we are told by an excellent authority (the Rev. Mark Pattison, "Suggestions on Academic Organization," p. 241),—for whose accuracy I would vouch in this matter were there any need so to do,—"*have corrupted the nature*" of a large class of young men amongst ourselves; whilst *the absence of a spirit of self-seeking* is, in its turn, the contradictory of a certain character which Mr. Mill (*l. c.* p. 90) has said to be one of the commonest amongst us adults, and to which Mr. Matthew Arnold has assigned the very convenient epithet of "Philistine." Investigation as to whether these undesirable tendencies are really becoming more rife amongst us, might be carried on with advantage in a place such as this, in the way of inquiries addressed to colonists returning home after a successful sojourn abroad. Such persons are able to note differences without prejudice, and, *ex hypothesi*, with unjaundiced eyes, which we are apt to overlook, as they may have grown up gradually and slowly. But, perhaps, researches of this kind are not quite precisely the particular kind of investigation with which we should busy ourselves; neither would the leaders of fashion, the persons with whom all the responsibility for this illimitable mischief rests, be very likely to listen to any statistics of ours, their ears being filled with very different sounds from any that, as I hope, will ever come from Section D. Whether men of science in England are more or less amenable to blame in this matter than the rest of their countrymen, it does not become us to say; but it does become and concern us to recollect that we have particular and special reasons, and those not far to seek, nor dependent on authority alone, for believing and acting upon the belief that real success in our course of life is incompatible with a spirit of self-seeking and with habits of even refined self-indulgence.

Botany and Zoology.

On the Effects of the Pollution of Rivers on the Supply of Fish. *By* Colonel Sir James Alexander, *K.C.L.S.*

Note on the Changes produced in Lotus corniculatus *by Cultivation.* *By* Prof. T. C. Archer, *F.R.S.E.*

During a late visit to the Shetland Islands, my attention was called to a singular transformation produced by giving greenhouse cultivation to the hardy and beautiful *Lotus corniculatus* so common in our fields.

One of the most agreeable spots in the Shetland Islands is that on which the interesting garden and hospitable mansion of Miss Mowatt is situate on the south side of the island of Bressay. The garden is especially interesting; for in it the

triumph of genius over natural difficulties is constantly shown, in the unremitting exertions of the fair proprietor to cultivate all the plants capable of introduction, and also the native plants which, with care, conduce to the beauty of the pastures.

Amongst other familiar denizens of the hill-side, the *L. corniculatus* has been a favourite for pot-culture with Miss Mowatt, who has found a very remarkable change to take place in that plant under cultivation in her greenhouse. From being procumbent and herbaceous, the stems become erect and woody, rising in the largest plant I saw to the height of something over 3 feet; the wood of the stem being extremely hard, approaching that of the *Medicago arborea* found in Italy, whilst the leaflets are increased from the usual number of five to seven. These shrubby plants, from all I could ascertain, are easily propagated by cuttings, but do not bear seed. They are, however, valued as evergreen window-plants; and I saw several so cultivated in Lerwick, all derived from Miss Mowatt's plants in Bressay.

On the Osteology of Chlamydophorus truncatus. *By* EDWARD ATKINSON, *F.L.S.*

A fine male specimen of this little Edentate, now nearly extinct in its sole habitat (Mendoza, Argent. Rep. S. A.), having been presented to the Philosophical and Literary Society of Leeds, has afforded a rare opportunity for reviewing and correcting the published accounts of its osteology. The adult animal is barely 5 inches in length.

Reference was made to its bibliography from Dr. Harlan, of Philadelphia (1825), to Prof. Hyrtl, of Vienna (1855), and Dr. Gray (1865).

Head.—The general conformation of the head is very remarkable, differing from all other Edentates in its relative dimensions, and excelling all its congeners both in altitude and in breadth, as compared with length.

Lower jaw has pachydermatous characters, *e. g.* its great depth, perpendicular ramus, rounded angle, and the shortness of its coronoid process as compared with the condyloid; yet it bears a resemblance to the jaw of the insectivorous *Macroscelides*, which has also a short coronoid.

Ear.—The external ear is unique in structure. There is no pinna; but a flattened and ossified acoustic tube, analogous to the meatus auditorius externus, extends from the tympanic bulla for a length of 4 lines, ascending over the zygoma, and terminating close to the eye by a delicate cup-like cartilaginous concha, which is protected and concealed by the fur just below the overhanging *chlamys.*

Scapula.—The shoulder-blade differs in form from all the Edentata, is curved downwards to a sharp point like a pruning-hook, has its dorsal surface divided by two spines into three nearly equal portions (as in *Cholœpus*). The upper spine supports an enormously long acromion.

Sternum.—The manubrium and first mesosternal bone have a sharp crest or keel, a vestige of a bird-like structure seen in a less degree in *Cholœpus* and *Dasypus*, and in the "interclavicle" of *Ornithorhynchus.* This feature, however, in *Chlamydophorus*, taken together with the ribs, which are ossified in front and articulated in the middle, is more ornithic than in either of these animals.

Pelvis.—Anomalous in all its parts. The pubis is open in front, as in the Sloths and the Shrews, but proportionately more than in either.

The *sphæroma*, or bony pelvic shield, which forms the characteristic truncated extremity of the body, is formed by the confluence of the *tubera ischii*, and strengthened by bony buttresses from the sacrum. The structure of this marvellous development was described in detail. It has no analogy to the cutaneous skeleton in the Armadillos proper; for in these the bony plates are never united to the pelvis or other normal parts of the skeleton by a true synostosis.

Dentition.—Ch. truncatus is a true homodont, with eight grinders on either side of both maxilla and mandible. They are slightly curved, so that each tooth, taken together with its antagonist, describes an arc of 25° with the convexity forwards. The first tooth of the lower jaw has no opponent, and therefore no masticatory surface. The eighth upper tooth is also without an antagonist, but, unlike its analogue in front, it has a double facet.

Mode of gait.—From various considerations it seems probable that *Chlamydophorus*, like *Myrmecophaga jubata* and *Manis*, walks on the back of its fore feet. This is inferred partly from the worn dorsal aspect of the strongly flexed toes, partly from the soft fur which clothes the radial half of the palm, but chiefly from the remarkable development of the *palmaris longus* muscle and the connexions of the palmar fascia.

Note on Pleuronema doliarium, *a new Infusorium. By* John Barker, *M.D.*

Professor Van Beneden exhibited a species of *Echinorhynchus* lent by Dr. John Barker.

Sur les Parasites. Par Prof. Van Beneden.

. . . . . On à souvent désigné à tort sous le nom de *parasites*, des animaux qui ne demandent à leur voisin qu'un gîte pour s'abriter, une place pour vivre plus à l'aise. Ils ne vivent pas aux dépens de leur voisin, et comme ils mangent souvent en commun, puisant au même plat, ils méritent plutôt le nom de commensaux. C'est ainsi que les Pinnathères vivent dans les Moules, les *Adamsia* à côté des Paguses, les Myriastomes sur les Comatules. Il y en a parmi eux qui renoncent complétement à leur liberté, commes les *Coronula* ou les *Tubicinella* des Baleines; ce sont des *Dikasites*; d'autres conservent toujours leur liberté, comme les Pinnathères que nous citons plus haut; ce sont des *Coïnosites*.

Les parasites véritables se répartissent également en diverses catégories; les uns hantent passagèrement leur hôte, ne logent jamais que dans les organes les plus éloignés, et sans communication avec l'extérieur; ce sont des *Xenosites*. Ils sont colloqués dans une cellule comme des prisonniers ou des fous, et ne peuvent songer aux soins de la famille. Comme les Cysticerques ils sont tous agames. Ils sont installés chez leur voisin comme une marchandise de *transit*.

Les autres sont arrivés au terme de leur voyage, s'établissent dans des organes ouverts, sur le passage des vivres, et s'occupent des soins de la reproduction: ce sont les Distomes et les Cestoïdes. Ils ont cessé de passer de l'un hôtel à l'autre, et vivent en famille chez eux. On peut leur donner le nom de *Nostosites*.

Enfin il en a qui s'égarent en route sans espoir d'arriver au terme du voyage, et que le hasard seul pourrait remettre sur le bon chemin; tels sont par exemple les vers vésiculaires et agames qui vont se loger dans les chairs d'un carnassier; ce sont les *Planosites*.

On Protandry and Protogyny in British Plants. By Alfred W. Bennett, *M.A., B.Sc., F.L.S.*

That self-fertilization is the rule rather than the exception even in hermaphrodite plants, has been recently admitted by most botanists. This may be effected either by the phenomena of dimorphism and trimorphism, by the fact that in the same flower the pistil and the stamens arrive at maturity at different periods, or by special contrivances for facilitating the carrying of the pollen by insects from one flower to another. This paper was devoted to illustrations from common British wild flowers of the second of these sets of phenomena, a number of instances being described in which the pistil ripens before the stamens (protogyny), the stamens before the pistil (protandry), and in which the two organs arrive at maturity at nearly the same period (synacmy).

On some Hybrid Sphingidæ and other Lepidoptera. By Edwin Birchall.

The hybrid moths were produced by the union of *Smerinthus ocellatus*, ♂, with *Smerinthus populi*, ♀. The larvæ were barely distinguishable from those of *Sme-*

rinthus populi, and appeared healthy: but there must have been constitutional weakness, for of 16 which assumed the pupa state, only 6 produced moths; of these, 3 were males, 2 females, and 1 hermaphrodite.

In form and colouring the influence of the female parent predominates in all the specimens, one only having the margin of the wings strongly denticulated, as in *S. ocellatus*. In the hermaphrodite specimen the right antenna is pectinated, and the whole of the right side of the insect presents the characters of *S. ocellatus*, the male parent, whilst the left or female side differs from an ordinary ♀ *S. populi* only by a little more brilliancy of colour. The generative organs are much distorted, and there were no ova in the abdomen.

The author also exhibited a series of *Hadena assimilis*, Doubleday, taken during the present summer in Scotland. This insect (possibly one of the forms of *Crymodes exulis*, Guenée) is interesting as a circumpolar species, found abundantly in Lapland, Iceland, and Labrador; Scotland seems to be the southern limit of its distribution. It is extremely variable, no less than 16 forms having received distinguishing names; and Dr. Staudinger states that out of 400 examples from Iceland and 20 from Greenland, in his possession, there were scarcely two alike. Only the variety *assimilis* has yet been observed in the British Islands.

Dr. Staudinger has described a larva as that of *Crymodes exulis* in the 'Stettiner entomologische Zeitung' for July 1857, p. 238, which has also been figured in Millière's 'Iconographie.' In its habits and structure, this larva resembles *Hevialus* rather than one of the *Hadenidæ*; and as it is not clear that *Crymodes exulis* was actually reared from it, the author thinks it probable some mistake has occurred, and that we are still ignorant of the early stages of the insect.

On the Steypireyör Whale of the Icelanders. By Henry Bird.

The Steypireyör of the Icelanders is identical with the *Balænoptera Sibbaldii* of Gray, the Rorqual of the Norwegians, and the Sulphur-bottom of the Americans.

Its average size is about 85 feet long, and 12 feet to 15 feet diameter in the thick part of the body; it frequently, however, attains greater proportions: one was caught off Iceland in 1866, having a length of 110 feet. They have been estimated to weigh upwards of 200 tons—about the weight of 3000 men. I have seen a fœtal whale which weighed 1740 lbs., and measured 18 feet $1\frac{1}{2}$ inch long.

The colour of the Steypireyör over the back and greater portion of the body is black, the chest and under parts being marked with greyish-white streaks, which sometimes incline to yellow. They are occasionally seen of a red colour, but this is owing to a red slime that covers the skin; this slime washes off after death. Such red whales are invariably very fat.

That part of the skin or blubber situated under the throat is divided into peculiar folds or wrinkles, which run longitudinally from the front of the jaw to the umbilicus. They reach in height to the top of the pectoral fin, and are eighty-two in number. This folded blubber is called Rungi by the Icelanders.

The form of the Steypireyör is the very ideal of symmetry; to compare it to that of other whales, it is what a fine clipper vessel is to a mud-barge; consequently it is capable of great speed. In their respirations they "blow" four or five times at each rising, and then dive for ten or fifteen minutes.

In sleeping, they float almost motionless on the water, breathing or spouting feebly at regular intervals; when I have so seen them, they have been in pairs, and invariably lying side by side, the head of one to the tail of the other, I presume for protection.

The blubber is 6 or 8 inches in thickness, and that from a good whale will contain 100 barrels of oil. It is a common error to suppose that this oily covering acts the part of a blanket for preserving the animal heat, at least so far as regards the oil, for oil is a good conductor of heat. It is a significant fact bearing on this point that the blubber of a mature fœtal whale I examined did not contain a trace of oil. Its real use, then, is as a storehouse capable of containing a vast supply of food.

The following is, I consider, rather an interesting fact: I found the oil contained in the blubber off the throat and tongue was nearly pure oleine, while that

from elsewhere contained 10 per cent. stearine. It is easy to imagine the effect that would be produced had the oil from these parts been of similar character to that from the rest of the body, they being so peculiarly exposed to the action of cold; for, on the animal going into freezing water, they (the throat &c.) would become so rigid as to cause it serious inconvenience, if not to endanger its life. I think the fact above observed likely to be of practical value to whalers; I would recommend them to keep the blubber from the afore-mentioned parts separate, limpid oil being more valuable than thick.

Specific gravity of oil from throat &c.	922·5
Ditto from other parts of the body	926·4

Average analysis of good blubber-oil	62·0
Dry gelatine, fibrine, &c.	11·5
Water	26·5
	100·0

In the spring, and also from the end of June to September, the Steypireyör is to be seen in great numbers off the east coast of Iceland; but up to the last few years they have never been hunted, as their capture was considered a matter of considerable difficulty and danger, owing to their great swiftness and supposed ferocity. They have generally been accredited with very murderous propensities, and with the habit of attacking and smashing the boats of the whalers; but this is a pure error: I have assisted in the capture of a large number, and they have invariably shown a timid and inoffensive disposition. The reason that they have been accused of such malignity of character has, I think, arisen through several accidents having occurred in consequence of their having been attacked with the ordinary harpoon in mistake for the Greenland whale, when, on feeling its sting, owing to their great strength and beautiful proportions, they are enabled to dive with such velocity as frequently to drag boat and crew under water.

They are exceedingly fond of each other; when one of a family is wounded, the others, perfectly regardless of their own danger, will remain by it until it dies. I saw one cow whale behave in such an extraordinary manner after her calf had been killed, that I concluded she had gone mad.

These whales are now captured by means of an implement termed a rocket-harpoon. This weapon is fired from a kind of gun or tube which is balanced on the shoulder of the harpoonsman: on its entering the whale, a shell with which it is armed explodes, and, provided the rocket has been well-aimed, causes instant death. The shell contains a bursting-charge of one pound of gunpowder.

Notes on Brackish-water Foraminifera. By Henry B. Brady, *F.L.S., F.G.S.*

The Rhizopoda of thirty-two brackish localities, comprising river-estuaries and lagoons at various portions of the British coast and the "Broads," "Meres," &c. of the Eastern Counties, had been examined, and the following conclusions drawn from the results:—

1. The different types of Foraminifera possess variable powers of accommodating themselves to decreased salinity of the water.

Of the forty-four reputed genera constituting the British marine rhizopod-fauna, only twelve are entirely absent from the brackish gatherings. Seven others may be regarded as only accidentally present and not at home in subsaline waters. Of the remaining twenty-five, seven, viz. *Cornuspira, Cristellaria, Polymorphina, Globigerina, Textularia,* and *Patellina,* have considerable adaptive power, but brackish specimens are invariably small and thin-shelled; they do not occur where the admixture of fresh water is very great. The genus *Lagena* is abundant in such localities, together with *Bulimina* (*B. ovata*), *Planorbulina* (*P. mediterranensis*), and *Discorbina* (*D. globularis* and *D. rosacea*). Lastly, a number of genera flourish in pools which at times contain only traces of saline constituents, viz. *Quinqueloculina, Trochammina, Lituola, Truncatulina, Rotalia, Polystomella,* and *Nonionina.* Specimens of *Polystomella striatopunctata* and *Nonionina depressula* had been found in fresh water.

2. The living Foraminifera of the fens may be compared with their immediate predecessors in point of time by the examination of the bed of clay underlying the peat throughout the district. Out of forty-one specific and varietal forms found subfossilized in the clay, twenty have survived the changes in the physical aspects of the country; no fresh type has appeared, and the few varieties which now exist, not present in the clay, generally represent depauperated conditions of certain of the older types.

3. Decreased salinity of water tends to produce certain changes in the characters of the Rhizopoda, especially in the nature of their investment. This is chiefly dependent on the deficiency of calcareous matter. Thus *Miliola* (normally porcellanous) and *Trochammina* (normally arenaceous) are represented in brackish water by forms having a keratose investment, which is scarcely altered by treatment with strong acids. In other genera the deficiency of mineral constituents causes thinning of the shell-wall.

Some species, notably *Nonionina depressula* and *Polystomella striatopunctata*, are often of a green colour when living in pools where the admixture of fresh water is considerable; and it was stated, under reserve, that there were indications that the colouring-matter might be chlorophyll.

4. Two species of Foraminifera hitherto undescribed are amongst the commonest of brackish Rhizopoda, viz. *Quinqueloculina fusca* and *Trochammina macrescens* *.

Eight species not before recorded from British localities had been found in the brackish gatherings, viz.—*Quinqueloculina Candeiana*, D'Orb., *Lagena Lyellii*, Seg., *Dentalina guttifera*, D'Orb., *Marginulina glabra*, D'Orb., *Textularia globulosa*, Ehrenb., *Gaudryina pupoides*, D'Orb., *Verneuilina spinulosa*, Reuss, and *Bolivina plicata*, D'Orb.

On the Terrestrial and Marine Fauna of the Strait of Magellan and Western Patagonia. *By* ROBERT O. CUNNINGHAM, *M.D., F.L.S.*

The author, after briefly adverting to the climate and physical features of the above regions, made some remarks on the distribution of the classes, genera, and species of the animals occurring therein, mentioning some of the more remarkable facts observed by him. Beginning with the Mammalia, the existence of the puma (*Felis concolor*), two species of ox, a *Mephitis* or skunk, an otter, the sea-lion (*Otaria jubata*), the fur-seal (*Arctocephalus falklandicus*), the guanaco, a species of deer, and a variety of Rodents were recorded from the Strait. No Marsupials were met with in Patagonia proper, but a small opossum (*Didelphis elegans*) not uncommon in the neighbourhood of Concepcion occurred in the island of Chiloe. More than eighty species of birds were procured in the Strait of Magellan and on the western coast of the continent as far north as Chiloe. The Raptores comprised two species of *Vulturidæ* (the turkey-buzzard and the condor), seven species of *Falconidæ*, and four of *Strigidæ*. Among the more interesting of the remaining land-birds enumerated were a humming-bird, a paraquet, and two species of woodpecker. In speaking of the water-fowl, some of the more remarkable breeding-stations of these birds were pointed out on a coloured chart of the Strait, certain of which had been observed by the old voyagers of the Elizabethan age. But one true reptile, a small lizard (*Ptygoderus pectinatus*), was recorded from the Strait of Magellan; but on the west coast of Patagonia Amphibia were found as far south as lat. 51°, and these consisted of two species,—one, the *Hylodes leptopus*, discovered by Mr. Darwin at Valdivia; and the other the type of a new genus named by Dr. Günther *Nannophryne*. About twenty species of fish were obtained; and of these, seven were members of the family Trachinidæ, and representatives of the genera *Amphritis*, *Chænichthys*, *Eleginus*, *Notothenia*, and *Harpagifer*. Reference was made to two new genera, *i. e. Maynea* (family Lycodidæ), and *Psammobatis* (family Raiadæ). The Invertebrata were then passed in review, and the more interesting forms remarked on. Regarded as a whole, the fauna of the Strait and Western Patagonia appears to belong to the Chilian type.

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* These have since been described and figured in the 'Annals of Natural History' for October 1870.

Note on the Embryo of the Date-Palm. *By* Prof. Alexander Dickson, *M.D.*

On the Foundation of Zoological Stations. *By* Dr. Anton Dohrn.

Dr. Dohrn gave an account of his exertions in Naples to construct a large building close to the sea, containing waste aquariums, extensive laboratories, and observatories, a scientific library, and whatever belonged to the practical pursuit of marine zoology. He asked the moral assistance of the British Association for overcoming some possible resistance at Naples, as the place for the establishment was to be had only by cession of territory of the Villa Reale, the celebrated park of the city of Naples.

He added remarks on the importance of zoological stations in other parts of the world, and said that his scheme was worked out with the view of facilitating the foundation of such stations.

On the Habits of the Indian Rock-snake (Python molurus). *By* Sir Walter Elliot, *F.L.S.*

The Rock-snake (*Python molurus*, L.) inhabits the whole of India, but prefers the dense forests clothing the base of the mountain-chains and extending, according to Mr. Swinhoe, even to China. In these haunts it attains its greatest size; and the statements made relative to its bulk and power of swallowing its prey, current among the natives, require to be carefully scrutinized, and only received with the greatest caution. Credible instances have been related by Capt. (afterwards Sir) Murray Maxwell of a specimen on board the 'Alceste' which swallowed a goat, the horns of which were seen distending the skin for many days afterwards. Lord Walden, President of the Zoological Society (when Lord Arthur Hay), described, in the 'Madras Journal of Literature and Science,' an individual 17 feet long which had swallowed a gravid axis deer. The case which I wish now to mention rests entirely on native testimony; but it was carefully sifted and tested by a very competent judge, the late Sir Mark Cabbon, K.C.B., Commissioner for the kingdom of Mysore. A Parsi merchant whom he had long known as a contractor for the commissariat when he (General Cabbon) was Commissary-General, called on him at Bungalore in 1835 or 1836, and in course of conversation mentioned that on landing at Coompta, from Bombay a few days before, on the Malabar coast, he had seen a rock-snake that had just been killed, having swallowed a bison (*Bos gaurus*). Although his informant was a person deserving of credit, the General determined to investigate the matter fully, and sent for the evidence of the most respectable eye-witnesses and who appeared most trustworthy. The sum of their testimony showed that the snake had been upwards of 30 feet long, that it had swallowed a young bison cow with the horns fully developed, and that it had been so completely gorged in consequence, that it had been unable to retire to its lair, which led to its discovery and easy destruction. The relation is given for what it is worth. It rests on what is allowed to be a sufficient amount of evidence for the establishment of a matter of fact, viz. the concurring testimony of a large number of eye-witnesses, recorded with care immediately after the event.

A specimen 11 feet long, kept in captivity for several days, showed no fear of man. It tried to seize fowls, dogs, &c. which approached it, but was checked by the rope which confined it. When the cord was lengthened it used to glide perpendicularly with the greatest ease up the smooth stem of a tamarind-tree near which it was picketed, and lie all day coiled on a branch. At length, wishing to destroy it, the basket in which it was secured at night was sunk for 36 hours in the river; but on being taken out it was found to be as lively as ever. Duméril and Bibron, however, state that all the Pythonidæ are aquatic in their habits, and *P. molurus* the most so; but its continued vitality after such prolonged immersion shows it to be amphibious.

Abnormal Petals on Flowers of Ranunculus aquatilis. *By* Thomas Gibson.

A clump covering some 6 or 8 feet in diameter, showing from 150 to 200 full-blown flowers, the principal part of which were beneath the surface, at depths

varying from a few inches to a foot or more, was discovered in a pit. The water was about 4 feet deep and quite clear, and gave full effect to the splendid array of such very unusual flowers.

When the stem is cut and left in the water, the petals of flowers which blow on the detached branch are not inflated, and are in form and size like those produced by *Ranunculus petalus-floribundus*, being broader and shorter, and having the nectary much more produced than those of *R. heterophyllus.*

It has no floating leaves, and its capillary or submerged ones are quite rigid, and having the peduncle opposite on a stem which is rather slender, very hollow, of a whitish-green colour, and semitransparent. The stipules are like those produced by *Ranunculus heterophyllus.*

The author has paid great attention to this *Ranunculus* each year, and has found abundance of flowers; but only a small portion of them with inflated petals, and those generally under water and always without a calyx.

After studying the habits of this curious plant carefully for the last five summers, he has come to the conclusion that it is capable of making a great effort to extricate itself when the water suddenly becomes too deep for it; and so, just as a man who had fallen into the deep would throw off his coat and his shoes to enable him to keep his head above water, this little plant, when in like difficulty, throws off its calyx and inflates its petals to enable it to reach the surface and there perform its usual functions in the sunshine in its usual way.

In 1865 there had been a heavy and rather sudden fall of rain, and the pit was much fuller of water than usual, which fully accounts for the great number of inflated flowers which were to be seen at that time.

Parasitic Habits of Pyrola rotundifolia. *By* Thomas Gibson.

During a few months' residence at Southport in the summer of 1869, the author spent some time and labour with a view of clearing up a difficulty respecting this plant, some naturalists considering it to be a parasite, while others hold the opposite opinion. He examined a large number of roots, but failed to find any situation where the Dwarf Willow (*Salix repens*) was not in company with the *Pyrola*, the roots being frequently so matted together as to render it almost impossible to separate them.

The long stoloniferous root of the *Pyrola* differs from the root of any other plant which has come under the author's notice. It is smooth, of a yellowish-white colour, and about one line or the tenth of an inch in thickness; it runs underground at from 2 to 3 inches below the surface, and threads its way amongst the roots of other plants for yards together, throwing off at various distances others, which, after threading their way for some distance, generally terminate by sending a young plant to the surface; the root-stock still proceeding and frequently making a turn almost at right angles, especially where it comes in contact with the root of *Salix repens*, the vicinity of which it never leaves.

Clumps of the *Pyrola* covering a piece of ground were frequently found several yards in circumference, which was evidently all growing from one underground root-stock or stolon. This root-stock sent out at intervals on the underside little tufts of small fibrous roots, of a dark but bright claret-colour, which contrasted beautifully with the white stolon out of which they grew. The roots of the Dwarf Willow are much thicker than those of the *Pyrola*, very woody, and of a light brown colour. Out of these roots there also grew at various distances little tufts of claret-coloured fibre, so like those which spring from the root-stock of the *Pyrola*, both in colour, shape, and size, that it was impossible to find a difference even with a good lens. These tufts of fibre, so much alike in both plants, were frequently matted together in such a manner as to render it almost impossible to separate them without breaking either one or the other.

Only one instance was found where the two plants were in actual contact with each other. One of the lateral shoots from the stolon of the *Pyrola* had penetrated the root of the Willow and stuck fast in it. The root was about the thickness of a good-sized office pencil, and in a state of decay. Whether that decay was caused by the root of the *Pyrola* sucking the sap, and so causing the death of the plant, or

whether its being in a state of decay, and of course soft, was the cause of the *Pyrola* entering; the author is inclined to think that the former was the case, and that for three reasons:—

1st. It had evidently been in contact some time, because the side shoot of the *Pyrola* had attained the full thickness of the parent root, which is not usually the case with the lateral shoots.

2nd. The white shoot, after entering the Willow, had become of the same brown colour, and the two roots were so incorporated together that it was impossible to say for a certainty where the one ended and the other began.

3rd. That the root did not go through the Willow, and so proceed on its way, as in all probability it would have done had the Willow been soft with decay when the *Pyrola* entered.

The author concludes that the two plants have a kind of sympathy for each other; and if it does not amount to the *Pyrola* being a parasite on the Willow, it certainly must have some mysterious affinity for it. He has found *Orobanche hederæ* with much less proximity to the Ivy than the disputed plants are to each other, and has also seen *Monotropa hypopitys* with no appearance of parasitic habits, and yet all naturalists believe these plants to be parasites.

Now, except it can be disproved by its habits and associations in localities which he has not yet had the opportunity of studying, the author must conclude the *Pyrola* to be a parasite upon the Willow.

On the Vegetable Products of Central Africa. *By* Col. J. A. Grant, *F.R.G.S.*

[For an abstract of this paper, see Appendix.]

Notes on the Whalebone-Whales of the Southern Hemisphere. *By* Dr. J. E. Gray, *F.R.S.*

[Printed in an extended form as the "Geographical Distribution of the Cetacea," in the 'Annals and Mag. Nat. Hist.' November 1870.]

On the Portuguese Globular Anchor-Sponge (Pheronema Grayi). *By* Dr. J. E. Gray, *F.R.S.*

[Printed *in extenso* in the 'Annals and Mag. of Nat. Hist.' October 1870.]

On the Abnormal Growth of Ferns. *By* Townshend M. Hall, *F.G.S.*

In this communication the author gave some results of his observations with reference to the increasing prevalence of abnormal structures amongst certain species of ferns in the south-west of England, but especially in Devonshire. He stated that his remarks did not in any way relate to the variations of ferns which had been subjected to artificial treatment under cultivation, but simply to the changes which appeared to have taken place during the last few years amongst those commoner species which abound in every wood and hedge-row. From the profusion in which they grow in the south-west of England, there are several species which may be looked upon as affording an excellent indication of that change, which, whether it may be called development, or whether it be considered retrogression, is so rapidly effecting an alteration amongst this tribe of plants.

Of the various species of ferns, the *Scolopendrium vulgare* appears to have been amongst the first to assume bifid and multifid forms, and so rapidly have they increased, either by sowing the spores or by inoculation, that there are now many localities where plants bearing abnormal fronds are the rule instead of the exception. Other common forms of this fern are the crisped and crested, narrow and ramose; all showing, however, the marked tendency of the species to depart from its normal structure.

Many other ferns, such as the following, have also recently appeared in the Devonshire lanes with bifurcated leaves:—

Polypodium vulgare (common polypody).
Lastrea filix-mas (male fern).
Pteris aquilina (brake fern).
Blechnum boreale (hard fern).
Polystichum angulare (shield fern).
Athyrium felix-fœmina (lady fern).
Asplenium adiantum-nigrum (black spleenwort).
Asplenium trichomanes (wall spleenwort).
Osmunda regalis (royal fern).

The abnormal growth of several of the above-named ferns is by no means constant; although under cultivation some of the variations of *Lastrea filix-mas, Polypodium vulgare*, and *Polystichum angulare* may be not only retained, but also improved upon. As an illustration of this the author mentioned a plant of *Polystichum angulare*, which he transplanted from a neighbouring lane into his fernery a few years ago, when it had only two or three fronds which were bifurcated, the remaining leaves being in their normal condition. Within twelve months all the fronds became bifurcated, and the succeeding year brought them out with a thickly crested multifid termination; whilst at the same time a fresh element of variation appeared in the bifurcation of each of the pinnæ or side leaves. In another season the pinnæ also had become crested, and so the whole plant has gone on, becoming more and more divided and subdivided, until all its original character has passed away; and the twenty-nine fronds of which the plant at present consists, and which ought of course in a normal state to have only as many terminations, have now become multiplied to such an extent that on the smallest and least crested of all the fronds may be reckoned no less than 137 small but well-defined terminations, whilst some of the larger leaves have upwards of double that number. During all this time the plant had never been moved or meddled with in any way, and the only attention it received was an occasional watering during the spring and whilst the fronds were sprouting out.

The fern which, in its natural state, is at the present time undergoing the greatest amount of change is the *Pteris aquilina*, or common brake. The observations of the bifid and multifid forms of this species were said to date from five years ago; up to which time the author knew of only one locality where an abnormal plant could be met with. Now the variations have increased to such an enormous extent that even in this short space of time this species bids fair to outstrip *Scolopendrium vulgare* in its race towards what, in strict botanical language, would perhaps be called "teratological metamorphosis."

The warm and moist climate of the south-west of England and the corresponding portion of Ireland appears more especially favourable to the growth of such ferns as have a tendency to depart from their original and recognized type; whilst, on the other hand, in the drier atmosphere of France and Italy, Spain and Switzerland, it was noticed that the ferns did not seem to have reached an equally advanced stage of abnormal growth. This question of geographical distribution was one of considerable importance, and as such was deserving of a full investigation.

In conclusion, the author said that the change now taking place so extensively amongst the Cryptogamia deserved to be especially observed, because it appeared to be a change of comparatively recent date. As far as he was aware, no instance of a fern with an abnormal growth had hitherto been noticed amongst the fossilized remains of the Old Red Sandstone, or in the still more luxuriant and diverse flora of the Carboniferous period, or even in any of the Mesozoic strata,—lower, middle, or upper; whilst, advancing a step further into the recent period, it was remarked that up to the time of De Candolle there was scarcely a botanist who had made any investigations in this department of botanical science.

Note on the Larval State of Molgula, *with Descriptions of several new Species of simple Ascidians. By* Albany Hancock, *F.L.S.*

The author of this paper shows that in two members of the genus *Molgula* the usual tadpole-like larva is developed, notwithstanding M. Lacaze-Duthier's recent discovery, that in a certain species stated to belong to this genus there is no such tadpole-larva, but that the young on escaping from the egg is a comparatively inactive Amœba-like creature. There is some probability, however, that the

species examined by this distinguished foreign naturalist belongs to another genus. Should this prove to be the case, the interest of his discovery will not be lessened on that account, as it would seem to establish the fact that the tadpole-larva condition is non-essential in the development of the Tunicata, and may have important influence on the doctrine of Kowalevsky respecting the relationship of the Tunicata to the Vertebrata.

The paper concludes with the description of two new genera, namely *Corella* and *Eugyra*, and nineteen new species of simple Ascidians.

On the relations of Penicillium, Torula, *and* Bacterium. *By* Professor T. H. Huxley, *LL.D., F.R.S.*

On a Pentacrinus (P. Wyville-Thomsoni) *from the Coasts of Spain and Portugal. By* J. Gwyn Jeffreys, *F.R.S.*

During the recent deep-sea exploring expedition in H.M.S. 'Porcupine' Mr. Jeffreys dredged, at a depth of 795 fathoms, between Vigo and Lisbon, specimens of a fine *Pentacrinus*, about a foot long. Associated with it were *Leda obtusa* and other arctic species of Mollusca, besides several kinds of simple and compound Corals and Hydrozoa. The tentacles or arms of the same species of *Pentacrinus* were afterwards taken by the dredge, in 364 fathoms, near the entrance to Cadiz Bay. In the latter dredging the Mollusca were mostly of a southern character, but included *Verticordia acuticostata* (a crag and Sicilian fossil, as well as living in the Japanese sea) and a few northern species, such as *Pleurotoma turricula* and *Trochus amabilis*. There were likewise some remarkable and apparently new Echinoderms, Corals, and Hydrozoa. This was stated by the author to be the first instance of a true *Pentacrinus* having been found in the European seas. Two species inhabit the West Indies, viz. the well-known *P. caput-medusa* and *P. Mülleri*. The species now exhibited had evidently not been attached at its base, which is quite regular and free, although it was imbedded in sandy mud, with the lowermost cirri serving to keep the *Pentacrinus* in an upright position, like the horizontal and spreading roots of a fir tree.

On an existing Favositoid Coral. By* W. Saville Kent.

In this communication the author gave a description of an existing coral closely allied to the Palæozoic genus *Favosites*, which he last year discovered among the collection of Madrepores contained in the Paris Museum. Unfortunately no record of the habitat of this interesting form has been preserved, though, at the same time, its recent origin is undoubted. The author has proposed to distinguish this form by the name of *Favositipora Deshayesii*. The author pointed out its close affinities to *Alveopora*, an existing genus common throughout the Red and Eastern seas, and from which it differed only in its possession of irregulary disposed, but perfectly developed tabulæ. Through *Koninckia*, a coral of the Cretaceous formation, it is immediately allied to the Palæozoic genus *Favosites*; and he affirmed to having recently discovered among the collection of fossil corals contained in the British Museum a form having no history attached to it, but undoubtedly referable to the American Devonian or Carboniferous deposits, in no way differing generically from the existing coral in the Paris Museum. He distinguishes this species by the name of *Favositipora palæozoica*. The author regarded the structure of *F. Deshayesii* as strong evidence in refutation of the theory advocated by Professor Agassiz, "that all the tabulate corals are to be referred to the Hydrozoa," its near ally *Alveopora* being such a well-known Actinozoon. He also expressed his opinion that no septate coral could justifiably be referred to that lower group,—septa being essentially intermesenteric developments, which could consequently be possessed by Actinozoa alone.

The author likewise referred to this form as bearing out his opinion that the

* This coral is figured and fully described in the 'Annals and Magazine of Natural History' for November 1870.

corals of the Palæozoic epoch were as highly organized as those peopling the existing seas. As he had shown, a species generically the same existed at that remote epoch, associated with members closely allied to *Alveopora*, but presenting a higher type of organization in their constant possession of tabulæ. In the genus *Favosites* the author also recognized an immediate connecting-link between the hitherto presumed distinct sections of the Tabulata and Perforata.

The author exhibited diagrams illustrative of the structure of *Favositipora Deshayesii*, and also photographs of the original specimens contained in the Paris Museum, these latter having been prepared for him through the kind courtesy of Professor Milne-Edwards.

Note on the Affinities of the Sponges to the Corals. By W. Saville Kent.

On a Stock-form of the Parasitic Flatworm. By E. Ray Lankester.

On Oligochætous Worms. By E. Ray Lankester.

Professor M. A. Lawson, M.A., F.L.S., distributed specimens of *Ribes spicatum* (Robson) which he had found growing in great abundance near Waterstein in Skye, and pointed out that the fruit-stalks were by no means always erect. He also drew attention to the excessively thick tomentum with which the leaves were covered.

On Abnormal Forms of Ferns. By E. J. Lowe, *F.R.S., F.L.S., F.G.S.*

This is a continuation of a paper read at Dundee. Wild varieties under cultivation are less permanent than if plants are raised from the spores of their abnormal fronds. It is possible to divide and subdivide a single frond into endless varieties of form, and to change the character of their reproductive organs. The fifty illustrations exhibited tell their own tale, and they are the result of the following experiments:—

1st. Spores were sown from a normal frond, and every plant raised was normal.

2nd. Spores were sown from a normal frond in the same seed from and in equal proportions with spores from an abnormal frond, and the result was that 90 per cent. of the plants were abnormal.

3rd. Spores were sown in separate pans from remarkably formed fronds, the result being plants like the parent from which they were gathered.

4th. Spores were sown from most singular-looking fronds, a dozen varieties sown together, the result being a large number of remarkable varieties.

5th. Spores were taken from a dozen of these most remarkable seedling forms, and they were mixed together, the result being even more extraordinary. In this experiment 4000 plants were raised, of which no two were precisely alike, and *not one* was of the normal form.

It has only been by mixing the spores of two or more varieties that the extraordinary forms now exhibited have been obtained. It therefore seems to follow that spores mixed together produce different varieties to those sown separately.

Report on the Testaceous Mollusca obtained during a Dredging-Excursion in the Gulf of Suez during the months of February and March 1869. *By* Robert M'Andrew, *F.R.S.*

The researches of the author occupied about six weeks, and extended throughout the Gulf of Suez—from the city of that name at its head to the island of Jubal at its entrance and Ras Mahommed, the point which separates it from the Gulf of Akaba. He had the good fortune to enlist Mr. Edward Fielding as a companion, and engaged the services of M. Susini as an assistant. The expedition was ac-

complished in boats; but being provided with tents &c., the party was enabled to spend a few days at numerous stations on the shores, at distances varying from ten to fifty miles apart.

The total number of species obtained, not including Nudibranchiates, amounted to about 818, of which 619 have been identified or described. In the list of named species about 355 were not previously recorded as inhabiting the Red Sea, of which 53, including 3 genera, are new to science.

In a recent work by Professor Issel, 640 species of Mollusca, *including* Nudibranchiates, are enumerated as the total number recorded from the Red Sea (including some doubtful), of which 191 were collected by himself in the Gulf of Suez.

The extraordinary dissimilarity between the fauna of the Red Sea and of the Mediterranean, which has been frequently noticed, appears to be confirmed by further researches; and although it is remarked by Issel that some of the Suez species seem to be so nearly related to their representatives in the Mediterranean and Atlantic that they may easily be supposed to have been originally the same, and that their distinguishing characters may have been acquired during the series of ages through which they have been separated, such species compose but a small percentage of the whole, and it is by no means certain that more remote localities, such as Japan and Australia, especially the former, do not furnish about as many examples of relationship to the European fauna.

The most important object of the report was to throw light upon the geographical distribution of Mollusca; but for this it would be required to publish at length the list of the species with the other localities at which they are recorded to have been found. It would then be shown that the number of Suez species common to Japan, the Philippine Islands, Australia, the Sandwich Islands, &c., prove a much wider distribution of the Mollusca of the Pacific and Indian Oceans than of those of the Atlantic, where the shores of America possess but few species in common with the coasts of Europe and West Africa. The fact of a species in several instances having been obtained from only two localities very remote from each other, such as Suez and Japan, is a proof of the very small amount of knowledge we possess of the fauna of the intervening seas.

Preliminary Report on certain Annelids dredged in the Expedition of H.M.S. 'Porcupine' (1869). *By* W. C. M'Intosh, *M.D., F.L.S.*

The specimens were chiefly procured from water under 500 fathoms, off the coast of Ireland. Amongst the few specimens of Nemerteans no new form occurs. The Annelids are on the whole of a northern type, many of the race having been previously procured by Mr. Jeffreys off the Shetland Islands, and well known in the northern seas generally. There were several new and most interesting species, including a *Sthenelais*, a form allied to *Leanira*, but probably requiring a new genus for its reception, a *Eunice*, *Nothria*, and *Chætogone*. The *Antinoë sarsi* of Kinberg and the *Petta pusilla* of Malmgren were, besides, added to our fauna.

On the 'Mortimer' Ship-aquarium. By Thomas J. Moore.

On Rhinodon typicus, *a rare Shark lately added to the Free Museum, Liverpool. By* Thomas J. Moore.

On work done by the Mercantile Marine of Liverpool in furtherance of Zoology. By Thomas J. Moore.

Exhibition of a remarkable hinged Fish-jaw and of a young Lamantin. *By* Thomas J. Moore.

On the Desert Flora of North America. *By* Dr. C. C. Parry.

The desert-tracts in North America, lying between 32° and 40° north latitude, comprise a series of interior basins shut in by mountain-barriers from the moist oceanic currents. These desert-districts, while varying somewhat in their physical features, owing to differences of elevation or geological structure, are characterized by an arid climate, scanty rains, and wide extremes of heat and cold, both annual and diurnal.

In the lowest depressions the local drainage is collected in the form of salt lakes or wide saline flats, the surplus water being lost by evaporation.

In the desert vegetation there is a marked distinction between the annual and perennial plants, the former being of slight texture, evanescent, and rapidly maturing, the latter exhibiting scanty foliage, frequent spinescent branches, and large tap-roots; the leaves are frequently coated with a copious resinous varnish, or clothed with a dense woolly tomentum, serving in either case to check growth.

The list appended to this paper contained 188 species, of which Dicotyledons are represented by 169 species, included in 48 natural orders and 144 genera. Monocotyledons include 19 species, comprised in 4 natural orders and 10 genera. The natural order Compositæ is represented by the largest number of species (44), nearly one-fourth of the whole. Leguminosæ, which includes most of the dwarf trees and larger shrubs, has 25 species.

On an Ebalia *new to the British list.* *By* C. W. Peach, *A.L.S.*

The author stated that the *Ebalia* was dredged by Mr. Jeffreys off Unst, Shetland, in 1864, and that it differed from all the other British *Ebalias* known to him, and then described it as follows:—"The carapace is pale, with faint whitish-pink blotches; the slightly raised pink tubercles are surrounded by white rings, giving the carapace a mottled appearance. The first pair of legs are equal in length, short, but very broad, the upper edges of the joints arched, with a sharp perfectly smooth keel. The other feet are slender, faintly granulated, and, in addition, have on the outer edges strong and long blunt spines; the upper joints have each a single row of 6 or 7, the two next generally two rows each; the lowest joint pointed and smooth. These spines on the smaller legs, with the very peculiar form of the larger ones, are so marked that he felt justified in naming it *Ebalia spinosa*. Should it have been found in the Scandinavian seas and described, this name must then be considered only provisional."

Notes on the Cuckoo-flower or Lady's-Smock (Cardamine pratensis). *By* John Price.

The leaves are, unlike those of other cresses, strictly compound, each leaflet being jointed, and very apt to drop off without decay or fading. They then act as seeds, producing one or more little plants, and, like seed-leaves proper, waste away as the embryo thrives. The terminal leaflet often gives birth to four or five plants; in one instance nine, in another ten were formed. This also takes place, without detachment or extra moisture, even in the linear leaves high up the flowering stem. The joints of the short petioles sometimes germinate too after the leaflets have fallen. From observations without lens ("by the *aid* of the naked eye," *Archer*) the radicle appears first, as a white thread on the upperside of the leaf, the plumule being at first enclosed in a green transparent vesicle, which bursts like an egg. The first plant always springs from the depression at the junction of the leaflet with its petiole, and those on the midrib precede the others, none ever appearing, as in *Bryophyllum*, on the outer edge. With this exception, the whole of the upper surface seems to bristle with life at every point, ready to break out under favourable circumstances. The phenomena may be promoted, and easily observed, by laying the leaves, in various postures, on wet blotting-paper, lint, moss, &c. in a dish, which should be frequently sprinkled with water. A dried specimen of the whole plant with many leaves germinating, *found under the ice*, was exhibited *.

* The author would be glad to furnish experimenters with good subjects. Address 38 Watergate Street, Chester.

On certain Principles to be observed in the Establishment of a National Museum of Natural History. *By* P. L. Sclater, *M.A., F.R.S.*

It having been now finally determined that the natural-history collections of the British Museum shall be removed from their present site to South Kensington, to form the nucleus of a national museum of natural history *, it appears to me that the principles upon which the proposed new institution are to be established and conducted are well worthy of the special and most serious attention of the British Association for the Advancement of Science. The inauguration of a National Museum of Natural History by one of the nations that have contributed most largely to the advancement of the natural sciences is an event that is not likely to recur very often. If the opportunity thus presented be properly taken advantage of, and the new institution started upon sound principles of administration and arrangement, there can be no doubt that a most material impetus will be given to the progress of natural science in this country.

Under these circumstances I think I need hardly apologize for troubling the Section with a few remarks upon certain points which appear to me to be most essential to be observed in the establishment of a National Museum of Natural History. These, I trust, will at all events provoke discussion, and induce some of the many distinguished naturalists present at this Meeting to turn their attention to this most important subject.

The energies of our rulers, especially in these troubled times, are too fully occupied with ordinary politics to allow them to bestow much care on such a matter, and unless it be forced on their attention by the British Association, or in some other authoritative manner, the result will be, I fear, that the system of administration now followed in the British Museum as regards the Natural-History collections will be transplanted along with the collections themselves, and the excellent opportunity of a grand reform, which may never again present itself, will be utterly wasted †.

The remarks which I propose to offer to the Section on this subject may be divided into three heads. First, I will say a few words concerning what appears to me to be the best mode of government of the proposed National Museum of Natural History; secondly, I will speak of the form of building which in my opinion ought to be adopted; and lastly of the arrangement of the collections within that building.

I. *Of the form of Government of the National Museum of Natural History.*

On this part of my subject I shall make but few remarks, having regard to the fact that, in common with many other of my fellow naturalists, I strongly committed myself on this point some years ago, and have in nowise changed my views since that period. In the memorial, of which I hold a copy in my hands, and which was presented to the Chancellor of the Exchequer in 1866, having been signed by 25 leading members of the Royal, Linnean, Geological, and Zoological Societies, it will be found to be stated that in our opinion the chief administration of the National Museum of Natural History should be entrusted to one officer, who shall be immediately responsible to some member of the Government. Those who are acquainted with the present mode of administration of the natural-history collections in the British Museum will, I am sure, readily agree to this proposed reform. It will be recollected that the government of the British Museum is vested by Act of

* On the 3rd of August last year a vote of £6000 was proposed in the House of Commons by the Chancellor of the Exchequer to clear the ground "for the erection of a Natural-History Museum" on the site of the International Exhibition at South Kensington, and carried, after a division.

† In the "bill to enable the Trustees of the British Museum to remove portions of their collections," prepared and brought in by the Chancellor of the Exchequer in 1862, it was proposed to be enacted that the trustees might remove the natural-history collections to South Kensington and certain pictures to the National Gallery. But, in a subsequent clause, it was proposed to be added that "*except in so far as was therein before expressed, nothing therein contained should affect the rights, powers, duties, or obligations of the trustees of the British Museum.*" At that time, therefore, it was clearly intended to continue the rule of the trustees over the natural-history collections when removed to South Kensington.

Parliament in a body of fifty trustees, consisting principally of great officers of state and of nominees of certain families whose ancestors have contributed to the heterogeneous contents of that building. Amongst these fifty trustees there are but two or three that are in any wise interested in natural history. Their secretary and chief executive officer is the present principal librarian, with whose great literary qualifications for his position every one is well acquainted, but who would not, I am sure, claim for himself in any sense the name of a naturalist. It will thus be seen that the actual government of our natural-history collections is at present vested in persons who have no special qualifications for the task. But, it may be said, there is the superintendent of the natural-history collections, and the keepers of the various departments into which they are divided—have they nothing to do with the administration? To this I reply, very little indeed, unless their advice is asked, or unless they choose to offer it. And, in the latter case, they can only address the trustees through the secretary, who is the only official present at the meetings of the trustees, and in whose hands, therefore, the administration of the natural-history collections is practically vested. This objectionable form of government, we think, ought to be replaced by appointing a director of the proposed new institution, "immediately responsible to one of the Queen's ministers." This simple form of administration has been most successful in other scientific institutions, such as the Kew Gardens and Herbarium and the Royal Observatory, and we believe it would be the best in the present case. It might, however, be advisable to give the director of the National Museum of Natural History a board of advice, composed of the heads of the principal departments into which the Museum is divided. Or another mode of softening the despotism would be to appoint a board of visitors, consisting of distinguished naturalists. These might be delegates from the principal scientific societies of the country, each of whom would be specially bound to see that the particular branch of science to the advancement of which his Society is devoted received its fair share of attention.

As regards the subordinate appointments in the National Museum of Natural History, these ought to be made, if not on the nomination of the director, at least not without his full sanction and approval. The director, being held responsible for the well-doing of the whole establishment, should certainly be allowed to select his own officers more or less directly. It is well known that some of the appointments made by the trustees in the departments of natural history in the British Museum have been, to say the least of them, in nowise felicitous, and that in one case at least great public scandal has been caused by the notorious incompetence of the person nominated. It is in vain to address remonstrances to a body of irresponsible trustees; but if the director is required to sanction every nomination, we shall know to whom to apply in case of any appointment not being up to the mark.

II. *Of the form of Building of the National Museum of Natural History.*

In discussing the form of building best adapted for a great National Museum of Natural History, let us begin by considering the principal classes of persons for whose accommodation it is or ought to be constructed. These are:—

1. The public at large, who go there to get a more or less general notion of the structure of natural objects and of their arrangement in the *systema naturæ.*
2. The student who uses the Museum for scientific purposes.
3. The officers of the institution, whose business it is to amass and arrange the collections.

In the opinion of most members of parliament, apparently especially of those who represent metropolitan constituencies, the first of these three classes is that whose accommodation ought to be first considered in the present case. In my opinion, and probably in that of most of those here present, the National Museum of Natural History ought to be constructed primarily for the accommodation of the third of the three classes; for, unless the officers of the institution have ample space and opportunity to examine and arrange the collection, it is obvious that neither the public nor the special student can be benefited thereby. At the same time I do not think that the public ought to be utterly excluded from their Museum four days in every week, as is now the case; and I therefore put it forward as an axiom

that some system of construction of the new Museum should be adopted whereby the public can be admitted all day and every day to view the collections without interfering with the scientific work of the establishment or with the special examination of objects by students. There is, so far as I know, only one plan by which this object can be carried out—namely, by arranging the exhibited objects in large wall-cases, to which access is obtainable from the back by doors opening into work-rooms adjoining the exhibition-room. In this way any ordinary object can be removed out of the series into the adjoining work-room, and returned to its place without disturbing the public in front of the cases, just as any article can be taken out of the shop windows in Regent Street without interfering with those who are looking into them from the pavement outside. This system of exhibition would be attended by the further very great advantage that the glass cases may be hermetically sealed on the side towards the public, and the ingress of dirt and dust thus prevented. Those who are acquainted with the filthy state of the specimens in the public galleries of the British Museum, in spite of frequent cleansings inflicted upon them, will readily appreciate the merit of this plan*.

This collocation of the exhibition galleries and corresponding working-rooms being insisted upon as of primary importance, the general form of the building must depend somewhat upon the site on which it is to be placed. My own belief, however, is that a hollow square, or something approaching that form, will in many ways be most convenient for a National Museum of Natural History, and the sketches which I now exhibit, which have been prepared for me by my accomplished friend Mr. Osbert Salvin, will serve to show the general plan of arrangement which I propose. The building might be of three or four stories, since, in the system of exhibition which I advocate, it would not be necessary to have top-lights. The basement, which might be partly below the surface, would be dedicated to taxidermy and to rooms for unpacking, storage, and mechanical work of all sorts. In the outer galleries running round the whole length of the ground story, I should propose to arrange the entire series of vertebrates from the highest mammal to the lowest fish. The specimens, according to the system already spoken of, would be placed in hermetically sealed glass cases along the inner walls of the galleries. The inner series of rooms surrounding the interior of the hollow square would be the working-rooms for the officers of the Museum and the students of natural history, and would communicate with the glass cases on the inner side of the outer galleries. Each set of working-rooms would, of course be in immediate apposition to the glass cases containing the corresponding series of exhibited objects. The lights to these working-rooms would be furnished from the inner sides of the hollow square.

In the first story of the building I should propose to arrange the series of invertebrate animals in exactly the same way, with the rooms for officers and students immediately adjoining them on the inner side.

The third story might contain the botanical and mineralogical collections, and perhaps certain others which it might not be possible to introduce into the general series, unless room could be found for these collections in the second story.

In a circular building, the centre of the hollow square, I should propose to place the library above and lecture-theatre below. The library might be connected by light iron galleries with the different working-rooms, so that the students of every department would have equally ready access to it.

Such is a slight outline of the kind of building I would propose for a National Museum of Natural History. It is, of course, a mere sketch, and there would be, no doubt, many difficulties in the details to be surmounted, but none, I think, such as an experienced architect would not be able to overcome. The advantages of this plan would be:—

1. The Museum might be opened to the public every day, without interfering

* In an admirable article on this subject in 'Nature' for May 26, 1870, Prof. Flower has attributed the original invention of this mode of exhibition to myself, I having first brought it under his notice. It appears, however, from a subsequent communication to 'Nature' by Prof. Flower (June 2, 1870), that the same plan had been already proposed by Dr. Hooker in the 'Gardeners' Chronicle' for 1858, p. 749. I can only, therefore, claim to be *an* (not *the*) original inventor of this method of arrangement.

with the scientific work of the establishment or of the students. Under the present arrangement, the collections are only open two or three days in the week, during which scientific work is suspended, as regards all objects in the public galleries.

2. The exhibited specimens would be much better protected from dirt and dust than they are in cases opening in front.

3. The exhibition of the whole series of organic beings in one continuous range of galleries would be much more instructive to the public than any system in which (as in the British Museum) they are dispersed about in different rooms.

4. The library, being in the centre, would be equally accessible from any one of the working-rooms surrounding the interior of the hollow square *.

III. *Of the Arrangement of the Collections in the National Museum of Natural History.*

The remarks which I have already made under the previous head will have served to show the Section that I am an advocate of what has been called the "typical," but what it would be better, perhaps, to call the "representative" system of arrangement of the natural-history collections. Nor am I able to understand how any reasonable person can seriously maintain that every object in a National Museum of Natural History ought to be exhibited to the indiscriminating public. In accordance with the views of the memorialists of 1858, who may be considered as having inaugurated the reform in our natural-history collections which I hope to see shortly carried out, the collections should be primarily separated into two series: (*a*) objects for public exhibition; (*b*) objects for private study. The class *a*, which is to be arranged in the public galleries behind the hermetically sealed glass cases, should embrace a very full and well-selected series of representatives of the principal forms of every class. In some cases it may be necessary to place in this category examples of every species of a group, in others only a selection of each genus or of each family. Every specimen exhibiting the external form in this series should be carefully prepared and mounted in a natural attitude. The representative species of the group having been selected, specimens of both sexes and of all ages should be placed in the series, as likewise examples of variation, if any such are known. The skeleton and other preparations of the internal structure should be added, as also the eggs and nests in the case of birds, and examples of corresponding structures in other classes. In short, the utmost endeavours should be made to illustrate, by preparations, models, and drawings, the life-history of the selected "representative" in as complete a manner as possible. To every exhibited specimen should be attached a printed label, giving its scientific and popular name, locality, and origin, and some short explanation regarding its chief peculiarities and most noticeable points of interest. There can, I think, be no doubt whatever that a small but well-selected series of any branch of the kingdom of nature, arranged after this method, would be of much greater interest and much more instructive to the public at large than ten times the number of objects arranged according to the present fashion of the British Museum.

On the other hand, the great mass of the collections (*b*) intended only for the private examination of experts should be treated after a very different fashion. In this division of the collections, the object is to arrange specimens in as small a space as possible, and, at the same time, in the most convenient manner for easy examination. The work-rooms immediately adjoining the part of the public galleries appropriated to division *a* of any class, will, of course, be devoted to the re-

* A great deal has been said by those who have advocated the retention of the natural-history collections in their present site, about the importance of keeping up their conjunction with the National Library. It is, of course, obvious that their removal will necessitate the acquisition of a special library of natural history for the new museum. I believe, however, that a library of the kind, sufficiently comprehensive for all practical purposes, can be got together without much difficulty and at a comparatively small cost, and that, when formed, it will be of much greater use for those working at the collections than the present overgrown establishment at the British Museum. It must be also recollected that the library of the British Museum is only available for the use of the officers. The books cannot be brought to the specimens nor the specimens to the books by ordinary students.

ception of division *b* of the same class, so that the whole *a* and *b*, being separated only by the partition-wall at the back of the glazed cases, which will be pierced by frequent doors, will practically form but one collection. In these work-rooms, moreover, should be assembled together the whole of the specimens relating to the particular class to which they are devoted. In the British Museum, according to the present system, the mounted specimens are in one room, the skins in a second, the skeletons in a third, and the spirit-preparations in a fourth. So that, in order to make a complete examination of a small mammal, for instance, it may be necessary to go to four or five different parts of the building, ranging from the galleries to the cellars, and from the extreme north-east corner of the former to the furthest south-west corner of the latter. In the new National Museum of Natural History, it is to be hoped, this inconvenience will be remedied by the entire amalgamation of the various collections of skins, mounted specimens, spirit-specimens, and skeletons into one uniform series. Besides the greater convenience of this mode of arrangement, another obvious advantage will be that the future student will be induced to devote his attention rather to the whole structure of the organism than to confine it to one particular part. If bird-cabinets were accompanied by skeletons and corresponding specimens in spirits, there can be no doubt that a much more perfect system of ornithology than any that we have yet attained to would be quickly arrived at. Our new National Museum must take the lead in this great reform, and set an example to other collections. In the same way, as every naturalist will allow, our conchological brethren will lose nothing by having the soft bodies of the mollusca close at hand to aid them in their investigations on the form of the external shell. There may be, of course, some exceptional cases in which it will be practically impossible to adopt this course; but, as a general rule, the principle should be insisted upon that every specimen, of whatever nature it may be, should be located in the rooms devoted to the reception of the class to which it belongs, and should be placed as nearly as possible in immediate apposition to its nearest natural allies.

To carry out these principles to their legitimate issue, I do not hesitate to support the view put forward by Prof. Flower and other naturalists, that the palæontological department of the British Museum, as at present constituted, ought to be totally abolished, and its contents distributed amongst the zoological and botanical collections, so that extinct forms may be studied in association with their nearest living representatives. The arguments in favour of this plan are, I think, unassailable; and although some little difficulties may be met with in carrying it out, there are none, in my opinion, that may not be overcome by judicious treatment. There is no doubt, I believe, that the progress of palæontology and palæophytology has been much retarded by the neglect of the students of the extinct forms of animal and vegetable life to make themselves sufficiently acquainted with the structure of the corresponding forms now in existence. So long as fossils were looked upon as the products of numerous successive and independent creations, there might have been some excuse for this mode of dealing with them; but now that we regard animated nature, past, present, and future, as one and indivisible, now that we acknowledge the stream of life, since its first appearance on this planet, to have been unbroken and continuous, let us exhibit its products, whether existing or extinct, in one continuous and unbroken series. The structure of an extinct organism can only be correctly understood after study of the nearest allies at present in existence. The best palæontologist must be he that has deduced his knowledge of extinct beings from comparison of their remains with the corresponding parts of those now alive. Those who appreciate these truths will not fail to allow that the proposed amalgamation of the palæontological collection with the general series in the new Museum of Natural History will be a decided step in advance, and one imperatively called for in the present state of natural science.

I have now, I think, touched upon some of the principal points on which changes are required in our present system of treatment of the collections of natural history belonging to the nation. It would be easy to go into further particulars in which reforms are needed. Especially I might call attention to the inadequacy in point of numbers of the present staff of officers in some of the natural-history departments of the British Museum, the insufficiency of the yearly sum allowed for ac-

quisitions, the vexatious regulations concerning the examination of specimens, and the miserably insufficient accommodation for private study; but all these things we may well hope to see altered in a new institution, and I will not take up time by enlarging upon them. In conclusion, however, I will recapitulate the principal topics touched on in the following propositions, which I trust the members of the British Association will agree with me in putting forward as the "platform" of reforming naturalists.

1. The administration of the new Museum of Natural History should be vested in a director, who should be immediately responsible to one of the Queen's ministers.

2. The collections should be primarily divided into two series,—those intended for public exhibition, and those reserved for private study.

3. The collections for public exhibition should be arranged in their natural order in one continuous series of galleries, so as to give the best possible general idea of the principal forms of life and of their arrangement according to the natural system.

4. The collections for private study should be arranged in rooms immediately adjacent to the public galleries, in such a manner that the corresponding portions of them should practically form but one series, and that the private student should have access at all times to objects in the public galleries.

5. A complete library of natural history should be furnished for the special use of the institution, and be placed in some central portion of the building, equally accessible to all departments.

6. The collection of osteology, the spirit-preparations, the skins in store, the series of British animals, the collection of "nests and nidamental structures," and all other subordinate collections should be amalgamated with the general series.

7. The collections of the palæontological department should likewise be amalgamated with the general series.

The Natural History of Hainan. *By* Robert Swinhoe, *F.R.G.S.*

This is a sketch of the natural history of Hainan, based on the observations and collections made by the author during his visit to the island, a narrative of which was read before the Geographical Section. The botany, climate, and geology are briefly touched upon; then follow remarks on the mammals, birds, insects, and shells which were collected, the affinities of the two former suggesting a wider separation in former times of the island from the Chinese main and its closer connexion with Cochin China.

On Hyalonema *and some other Vitreous Sponges.* *By* Professor Wyville Thomson, *LL.D., F.R.S.*

On some of the Echinoderms of the Expedition of H.M.S. 'Porcupine.' *By* Professor Wyville Thomson, *LL.D., F.R.S.*

Note on the Growth of Lodoicea Seychellarum. *By* Mr. Tyerman.

On the Structure of the Shell in the Pearly Nautilus. *By* Henry Woodward, *F.G.S., F.Z.S.*

After referring to the great interest attaching to the *Nautilidæ* on account of their vast geological and geographical range, the author proceeded to describe the shell with its septa and siphuncle, the latter being only found in the *Cephalopoda*, and nearly confined to the *Tetrabranchiata*. The camerated structure, however, is found in many mollusca (as *Spondylus*, *Euomphalus*, *Vermetus*, &c.). The author suggested that if any incipient character could be found leading up, as it were, to the siphuncle, we might fairly infer that it was only a more highly differentiated

form of shell-growth. Such incipient structure occurs in *Ostræa*, in which the shell-muscle (in aged individuals) dips down from layer to layer, offering a rough approximation to the siphuncle in *Aturia*. Mr. Woodward described the structure of the shell, and showed by actual dissection that no vascular system exists connecting the shell with the animal by means of the siphuncle. The siphuncle proves upon examination only to be a thin pearly tube, within which is another, composed of an extension of the periostracum, and quite destitute of structure. Shell-structure proves, when once formed, to be dead matter destitute of change, save where actually *in contact* with the mantle of the animal, which alone can add to or repair the shelly covering.

A Statement in reply to the two Objections of Professor Huxley relative to certain Experiments. By H. Charlton Bastian, *M.D., F.R.S.*

The objections raised by Prof. Huxley, in his Inaugural Address, against certain experiments bearing on the possibility of the genesis of living things from not living materials were two in number. One was an objection of a practical character, and another purely theoretical. The former was to the effect that the very fact of its being possible to preserve meats of all kinds for years, by adopting almost exactly the same process as that which had been employed in these experiments, was of itself evidence sufficiently strong to excite a doubt as to whether there was not some source of error in these experiments, even though it had not hitherto been detected. The results of some inquiries which the author has since made show, however, that while the meats are subjected to a much higher temperature than had been supposed (this, too, for a prolonged period), organisms are to be met with even in provisions obtained from the most approved sources, and sold as "perfectly good" (see 'Nature,' Nos. 47 & 48). But although the quality of the provisions may not be affected by the presence of these organisms, the objection which was urged against such experiments as those of the author must lose its value, especially when the fact is also borne in mind, and which was freely confessed to him by one of the best preparers of these preserved meats, that in a certain number of the failures which occur, the cause of the putrefaction or mouldiness cannot be accounted for. In many cases the obvious failures are due to defective closure of the tin case in which the provisions are enclosed; but in certain of the failures, of course few in number, neither this nor any other cause of failure could be ascertained. The author then proceeded to consider the second or theoretical objection which had been started. Does it not seem almost incredible, Prof. Huxley asks, that the living things which are now supposed to be produced *de novo*, should be, in most cases, almost precisely similar to the lower forms of life which are ordinarily met with in organic infusion? Theory seemed only capable of being met by theory, and he claimed that in the consideration of such a question as this, which was admitted to be still an open one, the advocates of either of the two opposing views must not strongly urge an objection which, though it might be good and valid if all the world thought with him, would turn out to be not valid at all if the views of his opponents were correct. The author accordingly contended that although it might be extremely difficult, almost impossible, to explain the coincidence above referred to if every living thing did really originate from a preexisting living thing, the objection, on the other hand, so far from being an objection, was in reality only what might have been expected if the views which he and others hold are really true. He then pointed out why he thought that if living matter could arise independently of preexisting living matter, it would be only reasonable to suppose that such new-born living matter would not only be as plastic and modifiable as the lowest known living things are now admitted to be, but capable of rapidly going through even greater changes than are at present recognized. This being the case, from his point of view, a similarity between the developmental forms resulting from new-born living matter and the organisms usually met with in infusions was only what might have been expected. Our present state of knowledge does not permit us to say which or

what combination of the physical influences now existing is most potential in bringing about the supposed transition from the not living to living modes of combination; and therefore it is impossible to say how far the apparent very great difference in condition in certain of these experiments ought to have left its impression upon the living things met with. If we could only be as sure of starting with materials of precisely the same molecular composition, which, however, was impossible, the author was inclined to believe that we might be able to procure definite kinds of organisms, almost as surely as we could now produce different kinds of crystals. He afterwards fully discussed the various possibilities of error in his own experiments, and gave reasons why he thought that none of these sources of fallacy had existed in four of his own experiments which were made in concert with Dr. Frankland.

On the Theory of Natural Selection looked at from a Mathematical Point of View. By ALFRED W. BENNETT, *M.A., B.Sc., F.L.S.*

The author gave in his adhesion to that portion of the Darwinian theory which maintains the evolution of species from a common ancestry, but held that that part of the hypothesis which regards natural selection as the prime agent in bringing about these changes rests on a much more debateable basis. The title of Mr. Darwin's great work, 'The Origin of Species by means of Natural Selection,' is itself a misnomer, since it only attempts to account for the survival and perpetuation of certain among a number of "spontaneous" variations. Taking the remarkable facts of mimetism, so largely insisted on by Darwinian writers as a bulwark of their theory, the author maintained that this explanation really breaks down at the outset. Two points admitted by all advocates of the principle of natural selection are, that it always acts with extreme slowness, and that every step must be directly of advantage to the species which simulates the outward form of some other species, or of some inanimate object. Proceeding on this basis, and applying mathematical calculation to the solution of the problem, it was attempted to be shown that the earlier steps in the transformation cannot have occurred through the operation of natural selection, because they must be entirely useless to the individual, and that the chances against the accumulation of a sufficient approximation towards the species ultimately mimicked, on which the principle of natural selection could operate, is something like ten millions to one, even when every advantage is thrown into the scale of the natural selectionist. The author then proceeds to show that even Mr. Darwin does not claim for the principle of natural selection the origination of the tendency to variation which is the foundation of all differentiation of species on the hypothesis of evolution. Since, therefore, some other principle, at present unknown to us, originates these variations, what right have we to say that this principle then ceases to act, instead of being the main agent in all the other subsequent changes? Of the laws of variation, Mr. Darwin says, our ignorance is profound. The paper then points out the remarkable analogy that exists between the exhibition of the phenomena of mimetism and the development of instinct. Both faculties are absent in the whole of the vegetable kingdom, very feebly apparent in the Protozoa and Cœlenterata, but slightly in the Mollusca, appear with extraordinary perfection in the Insecta and Arachnida, are comparatively in abeyance among the Pisces and Reptilia, and again strongly developed in the Aves. This parallelism would appear to indicate a closer connexion between mimicry and instinct than has been generally supposed. One of the founders of the theory of natural selection, Mr. A. R. Wallace, displays, in his recently published volume of 'Contributions to the Theory of Natural Selection,' a strange want of faith in his own principle, by denying its potency in the case of the evolution of man from the lower animals, and even in producing the different races of mankind. The same laws, the writer thinks, must be supposed to govern the whole organic world; and if some other principle, connected with man's reasoning powers, must be looked for to account for his raising himself from the brutes, the same principle, connected with the instinct of animals, must be applied to account for their power of developing new

species adapted to the circumstances of their environments. In conclusion, the author considered that although the discovery of the law of natural selection marked an era in the history of natural science, and gave a wonderful impulse to original research, the danger now is that the law will be pressed into services which have no claim upon it, and that in the hands of injudicious partisans it will become a hindrance rather than an aid to science, by closing the door against further investigations into other laws which lie behind it.

On Protoplasm and the Germ Theories. By Gilbert W. Child, *M.A., F.L.S.*

After an examination of the various germ theories which had been put forward, the author said it appeared to him that abiogenesis in some form or another was a necessary consequence of certain other theories which were gaining ground at the present moment, by the Darwinian hypothesis and the theory of evolution. It was hardly conceivable that we could theoretically hold that the original simple forms from which the whole animal and vegetable world had been developed, had sprung into existence out of the regular order of the evolution of the universe. What was called the germ theory of disease threw an interesting light on the question. Zymotic diseases were now generally believed to result from the multiplication and reproduction of germs in the blood of the man or animal affected. The matter to be accounted for was how the disease-germ appeared, disappeared, and afterwards again cropped up in the same district at great intervals of time. If the old theories were to be maintained in their entirety as to the fixity of species, every one of these diseases must have existed somewhere from the beginning. That was a view which was hardly credible, but it was held nevertheless. On the other hand, the hypothesis of the evolution of these germs *de novo*, by abiogenesis, would account for such phenomena in an intelligible manner. In conclusion, the writer was far from thinking that abiogenesis is *proved* to take place at the present time. His own experiments, published in the 'Proceedings of the Royal Society,' 1865, did not pretend to prove this. It is quite possible, and indeed probable, that the small moving masses of protoplasm found by Dr. Beale and himself in his experimental vessels might, as suggested by the President in his Address, have resisted the boiling temperature to which the contents of those vessels had been subjected. If this were so, it no doubt nullified the evidence of those experiments so far as they tended towards the solution of the main question at issue; but if so, it equally nullified the evidence of M. Pasteur's researches, on which the opponents of the doctrine of abiogenesis rested their case. The latter were therefore reduced to this dilemma, either these minute organisms which were found in the experiments of the writer and others can withstand the boiling temperature, or they cannot. In the former case, there is no evidence left on either side; in the latter they must have been produced by abiogenesis.

On some of the more Important Facts of Succession in Relation to any Theory of Continuity. By Dr. Cobbold, *F.R.S., F.L.S.*

The author remarked that for several years past the Biological Section had permitted, if it had not actually encouraged, the reading of papers on the theory of natural selection. The facts he had here selected for exposition were such as represented what might be termed the apparent chronology of the organic series, or, in other words, the ascertained times of the coming and flourishing of the larger animal groups. A true conception of what was or ought to be understood by the expression "equivalencies"—botanical, zoological, or geological—lay at the basis of a correct appreciation of the significance of the records of animal, vegetable, or sedimentary rock distribution throughout all time. Further, he ventured to assert that the grandeur of the formative scheme of Nature, whether testifying to an evolutionary method of production or to a series of creative acts, few or many in number, could only be adequately realized by the naturalist whose powers of allocation and grouping enabled him to grasp the import of those relations. He then

proceeded to deal with the facts of succession, describing the various known groups, and glancing at the times of origin and succession of the placental mammals, saying the first thing that the record suggested was the rapidity with which the most divergent groups made their appearance. Of course there was no real basis for an assumption of coeval creation. It might be held, on zoological grounds, that we ought not to separate men and monkeys, but retain them as one under the ordinal title of Primates. He adopted the division of the placental series of Mammalia into twelve groups, not from any rigid belief as to their separate equivalencies, but because they were sufficiently distinctive for practical purposes, and form on the whole perhaps the fairest expression of grouping which our science could at present afford. After dwelling at great length upon the succession of the various groups, he stated that as regarded the highest of all, the placental division, he would only say that, as he understood the doctrine, the strictest demand of the development theory did not require, as was commonly supposed, a lineal descent as between Bimana and Quadrumana; but it was certainly held that either of these groups, as we now know them, might have been separately evolved from more generalized primatal types, the intermediary terms being possibly connected by a long antecedent and far more generalized common progenitor. In that connexion the most advanced evolutionist must own that the assumedly missing tertiary primatals constituted a great and natural bar to the popular acceptance of the theory of descent by natural selection. On the other hand, a multitude of considerations seemed to him to outweigh all the data thrown into the anti-continuity side of the balance.

On the Development of Germ-life. By Dr. F. Crace-Calvert, *F.R.S., F.C.S.*

The author has been engaged during the last twelve months in a series of researches with the view of determining if the germs of fermentation and putrefaction can be carried any distance from their source of production by a current of atmospheric air, and communicate their decomposing action to a fluid susceptible of undergoing a similar change. To answer this question, he has made many experiments, but will now only give the following details.

The first question was, what apparatus should be employed to deprive atmospheric air of the germs it contains.

He passed slowly (during four hours) a gallon of air first through a tube 2 feet in length, filled with cotton-wool, and then through another tube, 6 inches long, filled with small fragments of pumice-stone heated to redness.

Secondly, air was passed through the same length of cotton-wool, and then through 18 inches of red-hot pumice-stone. The two bulks of air thus purified were made to bubble slowly into pure water, deprived of animal or vegetable life. A drop of each of the fluids was examined under a microscope of 800 diameters, and the following results were obtained:—

	Water through which air of No. 1 experiment had been passed.	Water through which air of No. 2 experiment had passed.
After 1 hour......	No life.	No life.
„ 20 hours	Two or three microzymes were present in each drop.	No life.
„ 36 „	Considerable amount of microzymes and vibrios.	No life.
„ 14 days	An increased quantity of life	No life.
„ 15 „ ...	Same.	One or two microzymes observed in each drop.

Having thus found the method of depriving atmospheric air of its life, he employed the same purified air to ascertain if he could, as stated above, convey by

a current of it the germs produced in one mass of matter into another. To effect this, the purified air was made to bubble through a pint of fluid in an active state of alcoholic fermentation, one of acetic fermentation, one of butyric, and in one containing putrid meat. The results were, that a very small quantity of life was observed under the microscope after several hours in pure water, weak sugar or albumen solution through which the air from the alcoholic or acetic fermentative fluids had passed; but it was in large quantities in the albumen solutions, in which the air had previously bubbled through the putrid fluid and butyric ferment,—thus showing that the germs belonging to the vegetable kingdom cannot be conveyed any distance by air in motion, whilst those of the animal kingdom are easily carried.

There are many experiments which the author intends publishing, but he limits himself to record only one, in consequence of the light it throws on many of the results published of late on spontaneous generation, viz. that if the albumen of a newly laid egg is mixed with pure distilled water free from life, and the whole exposed to the atmosphere for half an hour, life will be observed, and in an hour or two mycrozyma and vibrios will be found in considerable quantities; therefore no experiment as to the existence of life in fluids is of any value except when air has been excluded, and that the fluid intended for examination has not been exposed for a short time to the atmosphere.

The author hopes shortly to present to the Royal Society papers on the "Tenacity of Microscopic Life," "The Special Germs of Putrefaction," "Spontaneous Germination," and, lastly, "On the Germ Theories of Contagious and Infectious Diseases."

On the Controversy on Spontaneous Generation, with new Experiments.
By JAMES SAMUELSON.

The author discussed at length the present position of the controversy on heterogenesis, or the supposed creation of the lowest form of plants and animals *de novo*. He first referred to the theological bearing of the subject, which he believed to be overrated. But the author expressed his opinion, resulting from experiments and observations which extended over a long series of years, that those who prefer to adopt the theory of the creation of living forms only from germs already in existence would eventually find their view to be correct. He then proceeded to consider the recent experiments of Dr. Bastian, who believes that he has not only been able to create "protoplasm" by the combination of inorganic materials, as it was hinted possible some time since by Professor Huxley, but that under his hands there had been spontaneously produced from inorganic materials, combined in a manner circumstantially described by him, "truly organized plants and small ciliated infusoria." The author first criticized the terms in which Dr. Bastian had described the results of his experiments, characterizing them as vague, and giving instances of the vagueness. Then he showed how some of them were absolutely adverse to Dr. Bastian's own hypothesis; and finally he proceeded to describe at length a number of experiments of his own, made in June, July, and August last, and to compare them with notes of a series of experiments tried by him in 1863, which left little doubt on his mind that the plant types (mildew or mould) believed by Dr. Bastian to have been spontaneously produced in infusions, really spring from atmospheric germs, which, in some instances, become developed in the open air upon bare rocks and stones, but which the author showed to be present in rain-water fallen from the clouds, and in distilled water exposed to the air. The result of his experiments may be thus briefly epitomized:—In 1863 the author found the same plant types (various stages of mildew) in infusions of orange-juice, cabbage-juice, and pure distilled water exposed to the air; and during the past summer he again found the identical types in infusion of orange-juice, and in water caught in a shower of rain. At both periods, too, he found low animal types in the atmosphere. The author concluded his paper as follows:—"Here I leave to the judgment of men of science the results of my experiments, which any boy possessed of a microscope may repeat as effectually as I have performed them. And if the believers in

spontaneous generation still insist that their hypothesis has not been refuted, and that, assuming my observations to be correct, their view of the case has not been fully disproved, I am not prepared to deny this; but, on the other hand, I must be permitted to retort that their experiments have only proved, so far, their inability, notwithstanding all their precautions, to exclude invisible germs from their infusions. As to the mysterious appearance of these microscopical types on their solution *in vacuo*, what is it compared with the presence of some of the internal parasites of man and the lower animals? and who would have credited twenty years since the story of the wanderings and metamorphoses which those forms undergo before they find their way into the final habitat designed for them by nature? There is, however, very little chance of the controversy coming to an end at present. It is fascinating and sensational, and so far quite in accordance with the spirit of the age. Nor is it desirable that it should cease, for it is causing microscopical observers to direct their attention more and more to the beginnings of life and to the development of these living types, which are visible only with the aid of the lens; and I know of no subject more worthy of the consideration of biologists."

On the Scientific Value of Physical Beauty. *By* FREDERIC T. MOTT, *F.R.G.S.*

The purpose of this paper was to point out the connexion between the comparative beauty of objects and their rank in the scale of nature; to show that beauty is not bestowed capriciously, but has always a scientific meaning; that it is the index of maturity, of climax, of perfected function, and ought to be taken into account as such in every system of classification. The connexion between beauty and maturity was illustrated by natural facts, and a theoretic reason for it was suggested.

On various Alterations of Nutrition due to Nervous Influence. *By* DR. BROWN SÉQUARD, *F.R.S.*

On Apparent Transmission of Abnormal Conditions due to Accidental Causes. *By* DR. BROWN SÉQUARD, *F.R.S.*

Contribution to the Migration Theory. *By* DR. CATON.

This paper contained the results of a series of experiments on the phenomena of inflammation as seen in the transparent membranes of fishes and batrachians, chiefly in reference to the migration of blood-cells from the vessels, described by Addison and Waller, and more recently by Professor Cohnheim.

In the experiments on the frog the migration of colourless corpuscles was seen to take place from the vessels of the mesentery, though not in every instance. In the fish, notwithstanding close observation, the escape of blood-cells was never seen. Pus-cells were apparently formed in the tissues during acute inflammation. It was observed that venous congestion did not occur to the same extent as in batrachians and mammals,—possibly accounted for by the venous character of the heart in the fish. In the tadpole migration was seen to take place with the greatest activity whenever any considerable congestion occurred. In fishes and batrachians alike it was found that *general fever* caused the deposit of white blood-cells along the walls of vessels; and if, as in batrachians, great congestion subsequently occurred, the cells in contact with the wall were seen to migrate, the more readily if the wall of the vessel were thin and delicate, as in the tadpole.

On the whole it seemed probable that congestion was the main cause of cell-migration, and that the question whether red or white cells escaped depended merely on the one or the other being in contact with the wall of the congested vessel. Pus-cells appeared not to originate entirely from migrating blood-corpuscles; indeed it seemed possible that the two had no connexion with one another, and were merely accidentally associated: for in these experiments pus-cells had been

produced where there was no migration; and, on the other hand, blood-cells were seen actively migrating where all local inflammation had been carefully avoided.

On the Physical Relations of Consciousness and the Seat of Sensation: a Theory proposed. By* Professor John Cleland, *M.D.*

On a rare and remarkable Parasite from the Collection of the Rev. W. Dallinger. *By* Dr. Cobbold, *F.R.S., F.L.S.*

The author called attention to a microscopic preparation from Mr. Dallinger's cabinet marked "Hydatid from the Human Brain." It was clearly a cysticercus, differing, however, as regards its hooks, from the ordinary measle infesting man and the pig. At first sight its appearance reminded him of Dr. Weinland's *Cysticercus acanthotrias,* as given in his 'Beschreibung zweier neuer Tænioiden aus dem Menschen,' a communication published in 1851. A further examination would be necessary before finally pronouncing upon this point; but he was inclined to regard Dr. Weinland's triple-crowned cysticercus as a variety of a hitherto undescribed tapeworm, of which this specimen was the true normal representative in the larval state. At all events, it was a distinct form of armed cysticercus from the human brain, having been originally sent to Mr. Dallinger by a student at St. Bartholomew's Hospital.

Remarks on the Heart of a Chinese Dog containing Hæmatozoa, received from R. Swinhoe, *Esq., H.B.M. Consul, Amoy, China. By* Dr. Cobbold, *F.R.S., F.L.S.*

The author exhibited the heart in question, and gave an account of the zoological position and affinities of its contained nematode parasites. He remarked on the endemic character of the helminthiasis thus set up amongst the dogs of China, adding that the animal in question had, according to Mr. Swinhoe, "died at Shanghae in the month of April 1869, after three days of great suffering." He referred to similar preparations in the possession of Prof. Bennett of Edinburgh, and the Curators of the Museum of the Army Medical School at Netley. He disputed the question of its identity with M. Bohe Moreau's so-called *Spiroptera sanguinolenta,* showing also that it had no genetic relation to the *Filaria papillosa hæmatica* of Messrs. Grube and Delafond. The author had already discussed the probable nature of these latter hæmatozoa in his memoir "On the Prevalence of Entozoa in the Dog," first communicated to the Linnean Society.

Notice respecting the Embryonal Development of the Hæmatozoon Bilharzia. *By* Dr. Cobbold, *F.R.S., F.L.S.*

The author commenced by a reference to the researches of Bilharz, Griesinger, Leuckart, Weinland, and Harley in reference to this parasite, and remarked upon the severe endemics occasioned by its prevalence in Egypt, at the Cape, and at the Mauritius. He himself had first discovered this parasite in England when dissecting an African monkey which had died at the Zoological Society's menagerie, Regent's Park. The grounds on which he had altered the generic title (from *Distoma* to *Bilharzia*) were recognized as just, both abroad and at home. He had fully investigated the characters presented by the eggs, their contained embryos, mode of egress, movements, alterations of form, rapid growth, structure, behaviour under reagents, and various other particulars. He had likewise sought to rear them in slugs, insect-larvæ, Entomostraca, Gammari, and various fishes. From a patient under his care the author procured at least 10,000 eggs daily; and from these he reared ciliated cone-shaped embryos not unlike those of the common fluke, and showing a beautiful water-vascular system of vessels under high powers.

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On the Connexion of the Hyoid Arch with the Cranium. *By* Professor W. H. Flower, *F.R.S.*

In the sheep, as is well known, the anterior arch or cornu of the hyoidean apparatus is described as consisting of three bones, of which the uppermost is by far the largest and most important, and has received the name of stylo-hyal. This bone is long, compressed, and at the proximal end enlarges and divides into two short branches, by the anterior of which it is continued as a cartilaginous band to the cranium. The upper end of this band is again ossified in the form of a curved cylindrical plug of bone, with a truncated lower extremity, lying in a groove on the side of the tympanic bone, the edges of which groove meet around it in adult animals, and often become anchylosed with it; but this is only a secondary connexion. The primary connexion is with the periotic or petro-mastoid bone, immediately in front and to the inner side of the stylo-mastoid foramen. In embryonic specimens it can be traced as a distinct band of cartilage lying to the anterior and inner side of the lower end of the Fallopian aqueduct, and passing to the upper and back part of the tympanic cavity, near to the spot from which the stapedius muscle takes origin. This is, then, the true proximal extremity of the anterior arch of the hyoidean apparatus, if we leave out of consideration the stapedius and incus, which, there is reason to believe, are developed from the same rod of cartilage—a question which is not discussed in the present communication. Whatever may be the case with regard to the origin of the last-named parts, it is a subject of easy demonstration that in the sheep there is an ossified portion of the upper end of the hyoid arch, above and distinct from the stylo-hyal, which becomes firmly united with the periotic, and which may ossify either from a separate centre, or by extension of bone from the periotic. Whether it should be considered as a process of the periotic, or as a separate element, may still be a matter of opinion; but the existence of such a part as a distinct portion of the hyoid arch requires recognition. It may be conveniently distinguished by the name of *tympano-hyal*, as it is always in relation with the tympanic bone, and continues the hyoid arch up to the wall of the cavity of the tympanum.

This portion of the skull can be distinctly recognized at the spot indicated (*i. e.* to the anterior and inner side of the stylo-mastoid foramen) in almost all mammals, though in very different degrees of development, usually in accordance with the size and amount of ossification of the remainder of the anterior arch. Thus, in those of the Ungulata, as the ruminants, and especially the horse and rhinoceros, in which the stylo-hyal is very largely developed, the tympano-hyal is most conspicuous; but where, as in the pig, the anterior arch is little ossified, the tympano-hyal is comparatively rudimentary. In the Cetacea it is quite distinct, though small, and a fine band of cartilage can often be traced from the upper end of the stylo-hyal into it, imbedded in the great ligamentous mass which attaches that bone to the exoccipital and surrounding parts of the cranium, and which of course is only a secondary connexion.

In man this bone or process is also quite distinct, although it seems to have been generally confounded with the stylo-hyal. The so-called styloid process of the temporal bone has long been known to have a separate centre of ossification, and is also generally recognized as the homologue of the stylo-hyal of other mammals, one of the main points of difference being, that whereas in all others it is an independent bone not connected directly with the cranium, in man it is always anchylosed to the "temporal," and forms a process of the skull.

If a human skull at the period of birth is examined, a very small round piece of bone surrounded by a deep groove can be seen exactly where the tympano-hyal is found in the sheep, just behind the posterior limb of the inverted arch formed by the tympanic bone, and in front and to the inner side of the stylo-mastoid foramen. This increases somewhat in size as age advances, forming a distinct process, supported and partly embraced in front by the vaginal process of the tympanic. The true styloid or stylo-hyal at birth is a slender rod of cartilage, often partially ossified in the centre, and invested by a strong fibrous sheath, from which the stylo-hyoid, stylo-glossus, and stylo-pharyngeus muscles take origin. Though it occasionally becomes anchylosed in the adult with the tympano-hyal, as

is the case with those skulls which have very long styloid processes, this does not occur so frequently as is described in most works on anatomy. In the large majority of skulls, before middle age, the stylo-hyal is free, and is commonly lost in maceration. The short process which is always present, and which is commonly considered as a rudimentary styloid process, is really a distinct portion of the hyoid arch, corresponding with the tympano-hyal of the sheep.

The communication was illustrated by specimens and diagrams.

On the Correspondence between the Anterior and Posterior Extremity, and the Modifications of the Position of the Limbs in the higher Vertebrata. By Professor W. H. Flower, *F.R.S.*

This communication was chiefly devoted to an exposition, by means of specimens and diagrams, of the views held by most English anatomists of the serial homologies of the different bones of the extremities, founded upon comparison of the anterior, cephalic, or preaxial border of the one, in the primitive position, with the same border of the other, which leads to results opposed to the views of Wyman and other American anatomists, founded upon the principle of antero-posterior symmetry.

Comparison of the Thoracic and Pelvic Limbs in Mammalia. By R. Garner, *F.L.S.*

In this paper the author defended the teleological method of studying anatomy, as having led to many discoveries, and as the life-spring of much of its interest, at the same time deprecating a *nil-admirari* mood in these researches. A teleological explanation is not "a pretty golden ball to divert the racer from his course," but rather a golden thread to be traced throughout. He considers it legitimate to compare limbs &c. with an ideal *exemplar*, whether we adopt the apophysal origin for them or not. With respect to the latter theory he inquires, If the anterior limb is a dependence of the occipital vertebra, of which particular one is the posterior? He would rather refer a limb to several vertebræ (to five, perhaps), from their divisions and nerves of supply. He thinks the more multiplied rays of the fin of the skate but show a relationship to the *Sepia*; and, indeed, in the mollusks generally there is more of a gradation to the vertebrate skeleton than is commonly supposed. The abdominal fins of thoracic fishes are, however, as much removed forwards as the fore limbs of mammalia are backwards on the apophysis theory.

Few animals retain the most normal disposition of their limbs, the extensors all external, the flexors all internal, or in human anatomy anterior; some climbing animals, as the sloth or the seal, do so more than most; also man when he clasps or climbs, or more imperfectly, in his hind limbs, when he sits in the oriental fashion. An eversion has commonly occurred in the upper or fore extremity, an opposite inversion in the lower. In cursorial animals the former is compensated for by a pronation in the lower part of the limb; a still greater pronation in the mole causes the olecranon to point upwards, and the palm to be turned outwards, as it is in man in swimming. Few animals below the monkeys probably can supinate the hand; the squirrel does it from the wrist- and finger-joints. The author is disposed to agree with those who make the iliac fossa to correspond with the dorsum of the scapula, the external iliac surface with the subscapular dorsum, the rectus of the thigh with the triceps of the arm, the former looking more forwards and the latter more backwards than it should be: the humerus also to be rotated inwards to bring the two limbs at all to correspond. The patella and olecranon are variable in position &c., but homologues of each other; the thumb, radius, and external condyle preaxial and corresponding with the great toe, tibia, and inner condyle of the femur; the vessels and nerves at the elbow and knee are in the corresponding flexure surfaces; the dorsum of the foot, the patella, and the origin of the rectus in the lower extremity answer to the back of the hand, the olecranon, and the origin of the triceps in the upper, but not the groin to the axilla.

When we reflect on the situation of the arteries of the upper and lower extremities, we notice that at first sight they disagree with the above views,—that is, in the upper part of the limbs, the brachial artery being on the flexor, whilst the femoral is on the extensor aspect. For the artery of the thigh to be analogous to that of the upper arm, the popliteal should be a continuation of the ischiatic, and not of the femoral; and it is so in the fowl: in man also the ischiatic passes through the meshes of the lumbo-sacral as the brachial does through the brachial plexus. For the representative of the femoral artery in the arm we must fix probably on the acromial or some other of the higher branches. The direction in which the main vessels emerge from the trunk accounts for this.

MUSCLES.

Thigh.	*Arm.*
Psoas magnus, P. parvus, Iliacus.	Levator ang. scapulæ, Supraspinatus, Infraspinatus, Teres minor.
Pectineus, Adductors.	Pectoralis major, P. minor, Subclavius.
Gracilis, Sartorius, Tensor vag., Femoris.	Deltoid.
Gluteus maximus, Gl. medius, Gl. minimus.	Latissimus dorsi, Subscapularis, Teres major.
Pyriformis, Abductores breves.	
Rectus, Crureus, Vastus externus, V. internus.	Triceps, Anconæus.
Semitendinosus, Semimemb., Biceps, Poplitæus.	Biceps, Coraco-brachialis, Brachialis internus.

The above is a plan of the supposed homologies in the upper muscles of the limbs. The short abductors are only present in the lower extremity, and then most developed when the cervix femoris is longest and abducting force required. The deltoid is peculiar to the upper limb with the clavicle and acromion, this muscle agreeing with the iliacus and psoas only in its insertion between the extensors and flexors, but rather to be considered as belonging to the same category as the trapezius. This last is a protractor, whilst the lower parts of the latissimus dorsi and pectoralis major, or those parts continuous with the inner portion of their duplicated tendons, are its antagonists or retractors. The sartorius and gracilis appear the sole representatives of the tripartite deltoid, their insertion distant, but præaxial, between the flexors and extensors.

With respect to the innervation of the two limbs, it appears that each set of muscles, flexors, or extensors is supplied by nerves corresponding—that is, that no nerve to a flexor supplies an extensor. The median and ulnar nerves in the arm are purely flexor, the musculo-spiral extensor. The flexors have their supply especially from the fore part of the brachial and great sciatic plexuses, the extensors from the back, and pronators and adductors may be arranged with the former, supinators and abductors with the latter; the extensor nerves also being mostly given off high up, as are the origins of these muscles. The musculo-spiral in the arm represents the anterior crural in the leg, plus what answers to the peroneal, or part of it; in fact the musculo-spiral supplies all the extensors of the upper extremity, the anterior crural only those of the thigh, the peroneal helping it out in the leg, but sometimes arising high up in the plexus rather than in the middle of the thigh. The peroneal muscles in man are but partially extensors, but their tendons in some animals pass before the fibula. The pectoral nerves answer to the obturator, though the latter passes to its destination differently from what the pectorales do—of necessity, from the suppression of the fore part of the shoulder-girdle. Similar reasoning applies to the course of the musculo-spiral. The gluteal and subscapular draw from all the roots of the plexus, and any difference is only apparent. The several nerves of the latissimus dorsi and gluteus maximus also correspond.

In many animals the resemblance between the front and hind limbs is greater than in man; the differences are, as already in some measure shown, of an adaptive nature, especially in the osseous and muscular parts. In the fore limb we have a more varied volitional impulse, extensive pronation and supination, the opposable

thumb, a more intricate nervous plexus for the combination and separation of nervous influence, more easy to suppose in its details than to prove; the general arrangement of the body and the relations of trunk and limbs account for other differences, as the course of the vessels. How these modifications in the instance of limbs, and generally in nature, are brought about seems a mystery: it is allowable to doubt whether it is either by the gradual modifying action of external influences or by natural selection, or both together; and also allowable to believe that a species remains for ever the same till destroyed by adverse circumstances, and becoming the progenitor of other species by some unknown law of progression or development, connected probably with reproduction, and causing their sudden rather than gradual advent on the earth.

Albumen and its Transformation into Fibrin by the Agency of Water. *By* JOHN GOODMAN, *M.D.*

The author asserted that albumen is known as the *pabulum vitæ*, a substance into which all foods are said to be transformed by the digestive process. It is denominated the "raw material" from which all organic animal structures are ultimately formed, and abounds in the sanguineous and lymphatic systems. Yet albumen is not capable of giving general nutriment unless it be first transformed into organized material. Now that organized substance is fibrin. It is formed out of and at the expense of the existing albumen, and composes the white corpuscles of the lymph- and blood- and chyliferous vessels, and is found to constitute almost the entire mass of the organism. It supplies waste of tissue, is employed in the nutrition, growth, and reparation of the organism and in the reproduction of the species, and is vitally necessary for the performance of all the functions of the body. The transformation, therefore, of albumen into fibrin is a process of essential importance in the sustentation and maintenance of vitality itself; as necessary, indeed, as is the transformation of the inorganized substances of nature into the organized products of the vegetable kingdom, for the supply and sustenance of man and animals. Although this transformation is of such vital import, and these two substances are evidently dissimilar in their appearance and character, hitherto chemical science has been unable to discover any very clear and satisfactory distinction in their elementary composition; nor can the most able physiologist more than guess at the mode and means by which fibrin is developed in the animal organism.

Under a cognizance of these facts the author instituted some time ago a series of experiments having a special bearing upon these important questions.

Exp. 1. A portion of albumen from the egg was suspended in ropes in a glass vessel filled with pure water.

Exp. 2. Another similar portion was suspended in sea-water.

Exp. 3. The albumen was arranged in dilute alcohol.

Exp. 4. The albumen was suspended in the atmosphere; and in each instance the substance was left to stand for a period of from twelve to twenty-four hours or more.

In No. 4, after the period stated, the only observable change which had taken place was the evaporation of the water of its fluidity, and the formation of a brittle and still transparent rod.

In Nos. 2 and 3 a slight change only was perceptible, a very thin, flimsy, and almost transparent veil being seen to surround the suspended albumen.

In No. 1, however, in a very short space of time, *a beautiful opaque white veil* began to make its appearance upon the entire surface of the albumen, and bubbles of gas were seen to be eliminated. *The albumen gradually exchanged its simple, granular, transparent, and homogeneous appearance for that of an opaque white, fibrous, and organized formation, as seen by the aid of a microscope or powerful lens. Beautiful fibrinous threads of the most delicate construction were seen shooting forth in various directions and clinging to contiguous objects; and ultimately the entire substance under the microscope was found to consist of striated bundles of threads or fibrillæ*, resembling spun glass. (Specimens were placed upon the table.)

Any physiologist witnessing this product would be unable to pronounce it to be

any thing else than a beautiful specimen of genuine organized fibrinous substance. Hitherto we have not been able to collect enough of the gas to subject it to analysis.

These experiments, still being continued, appear to be fraught with incalculable results as regards nutrition, growth, and reparation of tissue, &c. in the animal economy, and the development of certain kinds of disease. Fibrin is of essential value also in the arrest of hæmorrhage and of the eruption of purulent matter among the tissues of the body, and appears to be a chief and fundamental source of all vital energy, strength, and function.

In No. 2 we have, as previously known, an illustration of the influence of neutral salines in the prevention of the formation of fibrin; and in No. 3, the reason why the London draymen and others, who so extensively indulge in alcoholic drinks, notoriously possess so little stamina and feeble constitutional vigour.

The *water-dressing* now so extensively employed in hospitals powerfully corroborates the results of exp. No. 1. We have often seen ulcers and sores of long standing, although previously devoid of any tendency to cicatrization, when subjected to the action of water in wet lint (covered by waterproof), in some twelve to twenty-four hours they very frequently assume an opaque white and fibrinous appearance, sometimes by a perfect bloom of the same covering the entire surface; or at other times by the formation of white edges, and little dots or islands of the same appearing in various parts of the sore; water thus effecting in the living tissues and fluids the same process, and repeating the experiment before us in the living organism itself.

This experiment appears to unfold a new view of the functions of the lymphatic and lacteal systems and absorbent veins. Excess of water cannot exist in the sanguineous system; but it is in the absorbents that not only is albuminous matter collected, but also water is absorbed from the circulatory system, the tissues, the atmosphere by the skin, and other parts of the system, *for the great and essentially important purpose, the transformation of albumen into fibrin*, by the admixture of the former with that fluid in their parietes, and in the lymphatic and mesenteric glands.

Finally, the product herein formed cannot be albumen, which does not coagulate at a temperature below 145° Fahrenheit, and this formation was produced in cold water. Either, therefore, the product of these experiments must be accepted as veritable fibrin, or some substance highly resembling the same, and not albumen; or the coagulation of albumen must henceforth be admitted to take place spontaneously in water perfectly cold.

Remarks on Variation of Colouring in Animals. By T. B. Grierson, *M.D.*

Variation in colour depends on modifications of albinoism in wild animals, and these modifications, hereditary, give rise to strange variations, which were illustrated by the exhibition of a number of specimens. A tendency was also mentioned of certain species to become black, illustrated by a number of specimens.

On the Antiseptic Treatment of Contagia as Illustrative of the Germ Theory of Disease. By William Hope, *V.C.*

On the Comparison of the Shoulder-bones and Muscles with the Hip-bones and Muscles. By Professor G. M. Humphry, *M.D., F.R.S.*

Referring to the view of rotation of the fore and hind limbs in opposite directions, propounded in his 'Essay on the Limbs of Vertebrate Animals,' and now admitted by most anatomists, he was of opinion that the extension of the same principle to the shoulder and pelvic girdles, suggested by Prof. Flower in the last Number of the 'Journal of Anatomy,' cannot be maintained. On the contrary, he gave reasons for believing that the outer surface of the scapula, behind the spine, together with the subscapularis and teres minor muscles, correspond with the outer surface of the ilium together with the glutei muscles; that the spine of the sca-

pula corresponds with the crest of the ilium, and the anterior edge of the scapula with the linea ilio-pectinea; and that therefore the supraspinatus muscle corresponds with the iliacus internus, and the hinder edge of the scapula with the hinder edge of the ilium. This was followed by a detailed comparison of the several muscles of the hip and the shoulder.

On the Homological Relations to one another of the Fins of Fishes.
By Professor G. M. Humphry, *M.D., F.R.S.*

The object of this paper was to show that the so-called "median" and "lateral" fins of osseous fishes are in reality serially homologous. It was shown that the "median" fins are, strictly speaking, double, each being formed by the coalescence of two lateral elements, produced in the two lateral laminæ (neural or hæmal, as the case may be) of the embryo. In the case of the ventral fins, the wider separation of the lateral laminæ being caused in this part by the presence of the abdominal viscera, the coalescence of the lateral elements of the fins is prevented, and each half remains as a distinct fin. The similarity of structure and appearance of the pelvic bones and their fin-rays to the interspinous bones and their fin-rays was pointed out, and the connexion of the pelvic bones and the interspinous bones with the rest of the vertebral skeleton was shown to correspond. The pectoral fins being admitted on good grounds to be homologous with the ventral fins must, if the view here taken is correct, be also serially homologous with the elements of the anal fin.

On Blight in Man and in the Animal and Vegetable World.
By Richard King, *M.D., F.E.S.*

The author having defined the terms Blight, Contagion, and Infection, according to the acceptance of these terms by the best authorites, proceeded to illustrate his paper on "Blight in Man and in the Animal and Vegetable World." He commenced with the fairy-rings, the eyesores in our parks and lawns, and he recognized two distinct forms not hitherto noticed—the fairy-ring withered and the fairy-ring luxuriant. In the fairy-ring withered grows the champignon in the periphery of the ring, in the luxuriant ring grows the mushroom throughout its entire ring. He then proceeded to the potato-disease, where he recognized two distinct forms—the withered haulm and the blotched haulm. He then proceeded to the rinderpest in the cow and the sheep, and he there recognized two forms of disease—the mouth-disease and the foot-disease. In man he recognized two distinct forms of disease—cholera and diarrhœa as well as fevers. He attributes all these diseases of the animal and vegetable world to one cause under two different circumstances, as gas passing out of the earth as a terrestrial gas and coming back to the earth as a poisonous vapour,—the gas passing out of the earth generating the withered fairy-ring, the withered haulm of the potato, and cholera; the poisonous vapour falling upon the earth producing the luxuriant fairy-ring, the blotched haulm of the potato, and diarrhœa.

Cui bono? Plough up the luxuriant fairy-ring, cut off the blotched haulm of the potato, and treat diarrhœa, all are amenable to treatment; but the fairy-ring withered, the potato-plant withered, cholera in man, and the rinderpest in the cow and the sheep are not amenable to treatment. Drive out of the infected locality man from his home, the cow from her shed, the glandered horse from his stable, and the sheep from his walk, and you will save them; do not leave them in the infected district to constantly inhale the poisonous gas which has produced the disease.

Note on Methæmoglobin. *By* E. Ray Lankester.

New Physiological Researches on the Effects of Carbonic Acid.
By B. W. Richardson, *M.D., F.R.S.*

On the Action of some Gases and Vapours on the Red Blood-corpuscles. *By* E. Ray Lankester.

Professor Alexander Macalister, M.D., exhibited a sketch of some varieties of the *Pronator quadratus.*

On a new Method of studying the Capillary Circulation in Mammals. By Dr. S. Stricker, *Professor of Experimental Pathology in Vienna, and* Burdon Sanderson, *M.D., F.R.S., Professor of Practical Physiology in University College, London.*

All conclusions as to the capillary circulation which are derived from observations of cold-blooded animals are subject to the objection that their functions are carried on under conditions considerably remote from those which exist in man. It has therefore been long desirable to change the field of research to mammalia. There is, however, no mammalian animal in which any external part is sufficiently transparent for observation under the higher powers of the microscope. The method must therefore necessarily involve vivisection; so that an anæsthetic is absolutely necessary. Most happily chloral is found to be completely adapted to the purpose. About three grains of chloral under the skin was found to be sufficient to render a full-sized guineapig motionless and insensible for many hours.

One of us (Dr. Sanderson) was familiar with the remarkable structure of the guineapig's omentum, and had already described it in connexion with another inquiry. The omentum of the guineapig is a membrane of extent relatively comparable to that of man, but its structure is entirely different. First, it is attached, not to the transverse colon, but to the greater curvature of the stomach; secondly, it consists, not of four layers of membrane, but two; and lastly, it contains very little fat, but in place of it a great quantity of cells, which are collected in a peculiar way about the blood-vessels and in their neighbourhood, partly in the form of perivascular sheaths, partly in the form of little collections or nodules consisting of cells lying in the meshes of a plexus of capillaries. Hence, from the simplicity of its anatomical relations, and particularly from its being attached on one side only to the stomach (in which respect no membrane is comparable with it), from its perfect transparency, from its abundant vascularity, and from its containing not only vessels, but living cells, and these cells of two kinds, namely, epithelial and parenchymatous, it is obvious that the omentum of the guineapig offers a splendid field for observation.

For observation the membrane must be immersed; immersed, however, not in water, for water would at once irritate and kill the tissue, but in solution of common salt of proper strength. Such a solution is what physiologists call an indifferent fluid, because, when it comes in contact with living cells, it does not appreciably interfere with their vital processes. Secondly, it cannot be in a natural condition unless it retain the temperature of the living body. The arrangement for securing this is somewhat complicated. The membrane is laid out in a glass dish, which is supported on the stage of the microscope by a hollow brass plate, through which a stream of water flows at a rate and temperature so regulated that the dish and its contents are maintained at a temperature closely agreeing with that of the body.

For commencing the observation this is all that is necessary. If, however, it is continued, the observer soon encounters two difficulties, both of which must be overcome. The one arises from the clouding of his objective when it is brought near the warm surface of the saline solution; the other, from the rapid evaporation of the solution, and the consequent alteration of its density, and eventual desiccation of the membrane. The first difficulty is obviated by warming the objective; the second by providing for the renewal of the water contained in the bath by the constant influx of fresh water at a rate corresponding to that at which it wastes.

The operative procedure is extremely simple. The guineapig having been thoroughly chloralized, is laid on a support or block, the upper surface of which is in

the same horizontal plane with that of the microscope stage. An incision is made, which extends for two inches at most from the outer edge of the left rectus muscle, a little below (behind) the end of the ensiform cartilage horizontally outwards so as to divide one or two costal cartilages. The muscles must next be divided and the peritoneum carefully opened. The stomach can then be drawn out of the abdominal cavity without difficulty, especially if the additional precaution be employed of first removing some of its contents. In doing this, very little manipulation is necessary, and special care must be taken to avoid touching the delicate structure attached to its border which is to be subjected to observation. The moment that the organ is fairly out of the abdomen, the membrane must be floated into the warm bath prepared for it, and is then ready for examination. It is, however, found very advantageous to cover those parts of it which do not lie directly under the microscope with sheets of blotting-paper. This arrangement has two advantages; the risk of evaporation is diminished, and the undulatory movements of the water are prevented, so that the object is rendered much steadier than it would otherwise be. The enlargements we have hitherto employed are inconsiderable, the most useful objective being the quarter of Ross. We have no doubt, however, that we shall eventually be able to apply both air and immersion objectives of higher magnifying-power.

The objects which present themselves to the observer in the omentum of the guineapig are manifold. We content ourselves with barely enumerating them. Veins and arteries may be studied of various diameters, some of them surrounded by sheaths containing fat-cells, some by similar sheaths containing the cells of which mention has already been made, others so free that their structure can be perfectly studied. Labyrinths of capillaries of surpassing beauty can be studied both in the sheaths of the vessels and in the little nodules of tissue in their neighbourhood; and finally the epithelial elements with their characteristic spheroidal nuclei by which the wonderful connective-tissue network of the omentum is everywhere covered.

After the conclusion of the Meeting the method was exhibited to a large number of medical gentlemen by the authors.

On Lefthandness. By Dr. P. H. Smith.

On the Cranial Osteology of Polypterus Birchii. *By* Professor Ramsay H. Traquair, *M.D.*

On the Intimate Structure of the Human Lung. By A. T. H. Waters, *M.D.*

On the Anthropology of Lancashire. By John Beddoe, *M.D.*

The author said that it had been supposed that the Teutonic character of the inhabitants of South Lancashire might date from the occupation of Manchester, during the Roman period, by a cohort of Frisians. Possibly the blood of the Celtic Britons, here as elsewhere, might have been somewhat affected by colonization of this kind under Roman auspices; but it seemed more probable that the southern part of Lancashire was not really Saxonized until the reign of Ethelfrith of Northumbria, who made great conquests in this direction. But the northern portions of the county remained British much longer, and were not thoroughly Teutonized until their colonization, in common with Cumberland and Westmoreland, by Scandinavians from Ireland and Man. Certain Scandinavians also found their way into South Lancashire, and thus a few local Danish names were found, such as Formby; and in Domesday Book certain Drenghs appeared as holding lands at Warrington, "drengage" being a Scandinavian tenure, and the word "drengh" being still in use in Norway. Since the Norman Conquest no ethnological change worthy of mention had occurred in the northern part of the county, and the physical type in

that quarter was accordingly pretty distinct. The Norwegian element prevailed in it over the Kymro-British. The Anglian was weak and the Gaelic doubtful. The stature was tall, the hair often light, and the features of Norse type. The evidence of philology pointed in the same direction. In South Lancashire the original Anglian type had been obscured by the prodigious extent of immigration; moreover, the stature had been degraded, and the type otherwise affected, by the results of the recent great development of manufacturing industry. It was, however, still distinguishable, and resembled that of Northern Mercia. The principal points in the paper were supported by numerical tables.

On the Ottoman Turks. *By* John Beddoe, *M.D.*

The observations of the author had led him to the conclusion that the physical type of the Ottomans, at all events of the peasantry of Anatolia, had not, probably, very much changed since the Turkish Conquest. At that time, no doubt, considerable intermixture of blood had occurred between the Seljukian and Ottoman Turks and the conquered people; but any subsequent crossing had been pretty much confined to Rumelia and the towns; and a well-marked Turanian physiognomy was still very prevalent among the Anatolian peasantry. The Turkomans were most Turanian in aspect, and next to them came the pastoral tribes called Yuruks, then the Anatolian peasantry, and, lastly, the Rumelians and the Mussulman population of the large towns, in whom the original Turkish element was extremely dilute. These differences of aspect corresponded to the known or probable differences of blood; and it appeared unnecessary to invoke the aid of supposed climatic influences to account for them.

On the Position of Australian Languages. *By* Dr. Bleek.

The author traced certain analogies between the several Australian and Dravidian languages, placing them all in Max Müller's great nomadic or Turanian class; and although the Australians have, with few exceptions, no grammatical distinctions of gender, the author does not think that this necessarily excludes them from the sex-denoting family. The use of suffixes and post-positions in the Australian languages led him to infer that they have been derived from the more temperate zones. Indeed the nations using suffix-pronominal languages are found on the outskirts of the Tropics, and in temperate and cold latitudes; while those speaking prefix-pronominal tongues are restricted to the Tropics. And, again, the suffix-pronominal class are addicted to sidereal worship, and the prefix-pronominal to ancestor-worship. The author, however, carefully showed that the physical descent of a race by no means necessarily coincides with the descent of its language; and, in conclusion, expressed his belief, based on a study of the mythology and the present customs of the Australians, that these have degenerated from a higher state of civilization.

New Views of Craniology. *By* F. Bridges.

On the Village System in India. *By* G. Campbell, *D.C.L.*

A Note on the Distribution of the Names of Weapons in Prehistoric Times. *By* Hyde Clarke.

The author observed that weapons in various parts of the world, of prehistoric date, were found to present extraordinary evidences of identity. He called attention to the possibility of finding evidences of identity of root-words in the names of weapons, and, as an instance, called attention to a name for arrow. This among the Sentals and Gonds of India is *sar*. The like form is to be found in many lan-

guages of Central India and Northern Bengal. In the Dravidian group a form is found also of *saralu*, and in Sanskrit of *sara*: this is also found in Nepal. On the Chinese frontier of Tibet it is *selima*. Crossing to East Africa, we have in Kigiude, a member of the great Caffre group, *musali*, *m* being a suffix.

On Ancient Sculptures and Objects of Art from Irish Cairns. By Eugene Alfred Conwell, *LL.D., M.R.I.A.*

If the early history of a country, at a period concerning which there are no written records, can be best studied from the instructive memorials of bygone ages, we have the advantage of possessing in Ireland some rare monuments of departed splendour, in the form of cairns, or ancient tombs, which still happily survive the ravages of time and decay.

The author's present intention is not to treat of the well-known tumuli at Dowth and New Grange, in the County of Meath; these, among archæologists, have had, and deservedly so, a world-wide fame. In the same county, however, there exists a much less known, and perhaps far more interesting series of cairns, which until recently have escaped all notice and investigation. Remarkable as they are, and reverenced and sacred as they must have been in former times, strange to say, these cairns have not yet been identified with any description or historical allusion in the ancient annals of the country.

During an excursion in June 1863 to the Loughcrew Hills, where these ancient tombs are most conspicuously situated, about two miles south-east of the town of Oldcastle, the author found the remains of thirty-one cairns, partially destroyed, no allusion to which was inserted on the Ordnance Maps beyond a few dots, with the word "stones" appended. The rural population of the neighbourhood believed these heaps of stones to be the magical work of a witch, and had current among them a legend to that effect. Hence the name given to the highest peak, Sliabh-na-Cailliglie, or "The Hag's Mountain."

After having made some preliminary explorations in two of the cairns, he had the good fortune to enlist the interest of the proprietor of the estate, the late James Lenox William Naper, Esq., in having a thorough examination of the place undertaken. It must, however, in justice, be stated here that, in securing his co-operation and indispensable assistance in supplying labour &c., the author was mainly indebted to the scientific tastes of his agent, Charles Wm. Hamilton, Esq., J.P., of Hamwood, who also communicated with Colonel Sir Henry James, R.E., as to the omission of these cairns on the Ordnance Maps; in consequence of which a highly qualified Sapper, Mr. Thomas Pearson, was sent from the Ordnance Department, Phœnix Park, with instructions to remeasure the hills, and to insert the antiquities on a map 25·344 inches to a statute mile*.

In a paper which the author had the honour of reading before the Royal Irish Academy on 26th February, 1866, he described these cairns, naming each by a letter of the alphabet, in some cases with an index figure. Out of the remains of thirty-one cairns, fourteen were found to contain parietal or chamber-stones, richly covered with sculptures; in some cases the work having been *punched*, and in others clearly and cleanly cut or *engraved*.

In each of the cairns careful drawings have been made of the devices upon these stones, amounting to 115 in number, several of which were exhibited to the Section. In the well-known cairn at Dowth there are eleven inscribed stones, and at the celebrated tumulus of New Grange twenty; while in Cairn T, at Loughcrew, as many as thirty-one, no two being exactly alike; and many most elaborately covered with devices, which afforded stronger evidence of their having been intended as symbolic emblems than the (in many cases) evidently ornamental sculptures at New Grange.

Cairn F.

The present remains of this cairn, which is $16\frac{1}{2}$ yards in diameter, rise only to the height of 5 feet. In the south-western corner of the southern crypt in the in-

* A copy of this map was exhibited to the Section, zincographed copies of which can be obtained from the Ordnance Publishers.

terior, and about a foot from the bottom, was found, imbedded among the clay and stones which filled up the chambers, a well-rounded stone ball, 3 inches in diameter; material probably brownish-red hematite.

Cairn H.

The present remains of this cairn, the richest of all in its yield of prehistoric objects, are only between 5 and 6 feet higher than the adjoining ground, and 18 yards in diameter. With the exception of about half a dozen large overlapping flags, the covering- or roofing-stones of the interior chambers had long since disappeared, leaving what remained of the original mound entirely overgrown with grass, and exposed to the destructive influences of rains and frosts. The unroofed passage and chambers in its interior were filled on top to a depth of about 18 inches with loose stones and earth. Having removed these, the author found the passage itself, from that to the bottom, a depth of about 3 feet more, completely packed with human bones in a fragmentary state, and nearly all showing evidences of having been burnt. Several hundreds of these human bones were collected on the spot and preserved, as they appeared to belong to persons of various ages and sexes. Of these were portions of skulls, shoulder-blades, limb-bones, &c. The three chambers of this cairn were found filled with a very miscellaneous mixture of stones, broken bones, and earth; the latter in a soft, stiff, retentive state. These contents were removed with great care; and from them were obtained the following:—One end of a bone bodkin; one half of a bone ferrule; six pieces of bone-pins, of which one, $1\frac{3}{4}$ inch long, and highly ornamented, still retains a metallic rivet, which apparently fastened on a head; one tine of an antler, 3 inches long; fourteen fragments of very rude pottery, being portions of urns; ten pieces of flint; upwards of 200 sea-shells, principally limpet- and cockle-shells; some varieties of small lustrous or shining stones; several hundred sea-pebbles, of various hues and sizes; a small brown stone ball; one round bone-disk, such as is found inserted between the vertebræ in the skeleton of a whale.

Underneath the stone basin in the northern chamber were found, imbedded in damp earth and mixed with small splinters of burnt bones, six stone balls, the largest about an inch in diameter; but they were in so soft a state that they could scarcely be touched without injuring them. Five of these appear to be white carbonate of lime, and the sixth a dark-coloured ball, probably made from a fossil, as it exhibits root-like fibres. Chiefly in the southern chamber, and for the most part imbedded in wet stiff clay, the author obtained the most remarkable collection of bone implements, glass, amber, iron, and bronze which probably has ever been found together under similar circumstances. In a few instances, where the bone articles chanced to be protected by an overlying stone, and in other respects in a dry position, the sound bone still retains its original polish, giving these articles all the appearance of being quite modern. In all other cases they were found in such a soft state that it was with difficulty they could be extracted from the tough clay without breaking them. Of these bone implements (nearly 5000 specimens, some in mere fragments), upwards of 100 are still perfect in form, and are of various shapes and sizes, some resembling in contour the flint knives of Scandinavia; some are perforated by a single hole near the end. Upwards of 500 of the fragments of these bone objects are ornamented with rows of fine parallel transverse lines. Seventy-three of them are engraved (twelve of these on both sides) in a very high order of art, with circles, curves, ornamental puncturings, &c.; and on one, in cross-hatch lines, is the representation of an antlered stag. Ten fragments of white and polished bone combs, of various patterns, turned up, seven of which are engraved on both sides, but the heads only and the roots of the teeth of the combs now remain. There is also a portion of another bone implement, highly ornamented, resembling in shape the cardboard upon which ladies in the present day are accustomed to wind silk thread.

Amber.—Four beads, the largest scarcely a quarter of an inch in diameter, and four fragments of other amber beads. *Glass.*—Three small beads, two blue and one green; two fragments, or broken pieces, of glass; one tapering piece of hollow glass (apparently) 1 inch in length, and resembling a shark's tooth or a Rupert's drop. *Bronze.*—Six open rings (that is, not closed into one solid piece), varying from $\frac{1}{4}$ to

$\frac{3}{4}$ inch in diameter; a portion of another ring, which is hollow, and formed by overlapping a thin plate of bronze, besides seven broken portions of other rings. *Iron.*—Not lying together, but mixed up with the earth and débris which filled the southern chamber, the author found:—seven specimens of iron objects; one is an open ring, about $\frac{1}{2}$ inch in diameter; one half of another ring, somewhat larger; two pieces, each about 1 inch long, of uncertain use; one thin piece, $\frac{3}{4}$ inch long and $\frac{1}{2}$ inch broad; one piece, $1\frac{1}{2}$ inch long, presenting the appearance of being the leg of a compass, a tool with which the bone implements were evidently inscribed and ornamented. Lastly, an iron *punch*, or pick, 5 inches long, with flat point or working end, with the head, or larger end, bearing evidences of being hammered, and thus indicating its use.

Many of the devices or designs upon the sculptured stones in the cairns have been executed in *punched* or picked work, in many cases each impact or stroke in the line being still quite visible. The author has fitted the point of this instrument to many of these punched patterns, and they afforded every appearance of having been executed with such a tool as this. In a later examination of the remains of this cairn (June 1868), assisted by two men, the following were found:—Nine small open bronze rings, of different sizes; one link, or ring, material probably steatite, nearly worn across in use in one place, and which may have been used as part of an ear-ring; one flint nodule, sponge-shaped, well polished on upper surface; one segment of a small brown stone ball; one thin rectangular disk of stone, veined in pink and blue shades of colour; two bone beads; two glass beads, one green and the other blue, differing in shape; one "*double bead*" of solid glass, about $\frac{1}{2}$ inch in length, and of a very soft green colour when held up to the light; fifteen portions of bone flakes or implements, one perforated, and five others engraved with circles and other ornamentations.

Cairn I.

In the compartment which exactly faces the east, on the surface of some finely broken stones, and underneath a thin flag which formed the floor of the chamber, the author found a bead and pendant, to all appearance portions of a necklace of stone.

Cairn J.

A roughly finished brown stone ball, about 1 inch in diameter, was found near the opening of the passage into the interior chambers.

Cairn L.

From among the loose stones which filled up the unroofed chambers here, the author collected upwards of 1000 portions of bones: two bone flakes, similar to those found in Cairn H: 154 fragments of very rude pottery; one piece, about 3 inches square, being the upper portion of an urn, is very inartistically ornamented with three slight ridges, and about an inch from the top there is a single perforation; another larger piece, ornamented with four slightly raised ridges, is perforated by two holes, one $1\frac{1}{2}$ inch below the other. When the interior chambers were cleared of all the loose stones &c., on Tuesday evening, 19th September, 1865, Mr. Naper, Mr. Hamilton, and Archbishop Errington were present at the raising of the remarkable large oval stone basin which occupied the floor of the northern compartment. Immediately underneath it were several splinters of charred, blackened bones; and, imbedded in the stiff wet earth below, the author found:—upwards of 900 pieces of charred bones, with about a dozen pieces of charcoal lying in various directions; forty-eight human teeth, in good preservation; the pointed end of a bone pin, $5\frac{1}{4}$ inches long; a fragment, 1 inch long, of a similar bone pin; a syenite ball, perfectly rounded, and still preserving its original polish, nearly $2\frac{3}{4}$ inches in diameter; another perfectly round stone ball, about 1 inch in diameter, and streaked with white and purple layers; another brown stone ball, dashed with dark spots; a finely polished jet-like object, oval in shape, $1\frac{1}{4}$ inch in length, and $\frac{3}{4}$ inch broad; eight white stone balls, quite in a soft state.

Cairn S.

The apex of this cairn is completely gone, leaving exposed the tops of the upright stones forming the chambers. Outside the entrance to the passage was found,

in white flint, a perfect specimen of a leaf-shaped arrow-head, $1\frac{1}{2}$ inch long and nearly $\frac{3}{4}$ inch broad. Dr. Thurnam, who has seen it, pronounces it to be somewhat larger than those of the same unbarbed type found by him in the Wiltshire barrows. The two small compartments into which the passage itself is divided were filled up to the height of 18 inches with charred bones, broken into small fragments. On the top of these, in the first chamber, a piece of bent bone was found, 9 inches long, tooled and rounded at one end, to all appearance being a broken portion of a bow. The most remarkable thing about it is that it has lain there so long that it is now silicified. In the second chamber, and in a similar position (that is, on the top of the charred bones which filled the compartment), the author found a roughly finished bone dagger, 7 inches long and nearly 1 inch broad.

CAIRN T.

Among the loose stones at the bottom of the central chamber, and close to the entrance to the northern crypt, was found a bronze pin, $2\frac{1}{2}$ inches long, with head ornamented and stem slightly so, and still preserving the beautiful green polish peculiar to bronze*.

The author does not propose offering any theories or opinions, contenting himself with the simple statement of facts, and leaving others to draw such conclusions from them as their various judgments may suggest. One fact, however, appears to him to be established, viz. that the cremation of the dead has been practised in Sliabh-na-Cailliglie up to a period when the people had become acquainted with the use of articles made not only of stone and of bronze, but of iron, glass, amber, and bone.

On the Discovery of Platycnemic Men in Denbighshire.
By W. BOYD DAWKINS, *M.A., F.R.S., and* GEORGE BUSK, *F.R.S., F.L.S.*

Mr. Boyd Dawkins described a refuse-heap at Perthi Chwareu in Denbighshire, and a sepulchral cave which he discovered close by, containing from twenty to twenty-five human skeletons, buried in the crouching posture, and, associated with a flint flake, a few fragments of marine shells, the mussel, cockle, and *Mya truncata*, and broken bones of animals. The latter were of the same species in both cave and refuse-heap, viz. dog, fox, badger, marten, wild cat, pig, roe, red deer, goat (*Bos longifrons*), Celtic short-horn, horse, water-rat, hare, and rabbit. The two deposits are therefore of the same relative antiquity. The same group of animals occurred also in the cave at Cefn, near St. Asaph, in which human bones were found along with flint flakes. The human skulls and bones also from a chambered tomb near Cefn are of the same character; and therefore the refuse-heap, the interments in the two caves, and the tumulus are probably of the same date. The human skulls are of the ordinary type termed "Ancient British," and some of the leg-bones present the peculiar character which is denoted by the term platycnemic, while others are of the normal shape. This diversity destroys the value of platycnemism as a character of race. It has not been observed before in any British skeletons. The presence of the flint flakes, coupled with the crouching posture of the skeletons and the shape of the skulls, proves that some deposits are of Neolithic age. Professor Busk pointed out the difference in the platycnemism of the Denbighshire skeletons and that in those which have been discovered in France and Gibraltar; and maintained that the evidence in favour of its being a race-character completely broke down. The remains found in Denbigh indicated a small race, averaging from 5 to 5 feet 6 inches in stature.

Exploration of the Victoria Cave, Settle, Yorkshire.
By W. BOYD DAWKINS, *M.A., F.R.S.*

The following are the results of the labours of the Settle Cave Exploration Committee up to the present date. In cutting a new entrance into the Victoria Cave, this section was exposed:—

* A collection of the most interesting objects found, and a series of drawings of the inscribed stones from one cairn, were exhibited in a large glass case at the Soirée given in St. George's Hall.

4. A talus of angular limestone fragments, fallen from the cliff, 2 feet thick
3. A stratum of dark earth, carbon, stones, Roman pottery, and coins, and fibulæ, broken bones, &c., 18 inches thick.
2. A talus of angular fragments of precisely the same character as that above.
1. A zone at the base of this furnished remains of a gigantic brown bear, red deer, horse, and *Bos longifrons*, a bone harpoon and flint flakes, and rested on the clay, which is of unknown depth.

This section affords a rough measure of the difference in time between the two periods of the occupation of the cave.

If we allow that for a considerable time past, immediately outside the historical epoch, the disintegration of the cliff has been equal, in equal times, of two feet,—if, then, in twelve hundred years, to put it at the lowest, only a thickness of twenty-four inches has been accumulated, it would take three thousand six hundred years for a deposit of six feet to be formed; and thus the harpoon and flint stratum would be about four thousand years old. The accuracy of this calculation is, indeed, injured by the possibility that the winter cold was more intense and the splitting action of the frost greater in pre- than in post-Roman times. Nevertheless the change from the arctic severity of the postglacial winter to the climate which we now enjoy in Britain has been so gradual, and spread over so long a period, that it may be assumed to have been very small in so short a time as four or five thousand years.

These two layers containing traces of man gradually coalesced as the excavation passed into the cave, and at last became so confused together as not to be easily distinguished at a few feet from the entrance. The remains of a gigantic bear, which had been eaten probably, may be assigned to the lower horizon, which furnished flint flakes and a bone harpoon in form resembling that used by the natives of Nootka Sound. The upper or Romano-Celtic stratum continued to supply evidence of the comparatively late date of its accumulation in barbarous imitations of coins of Tetricus (A.D. 267–273). A portion of the ivory handle of a Roman sword and a coin of Trajan have also been found, along with large quantities of the bones of animals that had been used as food. Several spurs of cocks proved that the inhabitants ate the domestic fowl, which was probably imported into this country either directly or indirectly by the Romans. The most striking object, however, is a beautiful sigmoid fibula made of bronze, and ornamented with a beautiful pattern in red, yellow, green, and blue enamel. It is an admirable example of the art of enamelling ("Britannicum opus" ?) which seems to be peculiar to the Celts.

On the Shadows of Genius. By W. C. Dendy.

On the Geological Changes which have Occurred since the first Traces of Man in Europe. By Professor P. Martin Duncan, *M.D., F.R.S., Sec. G.S.*

The Relation of the Ancient Moabites to Neighbouring Nations, as disclosed in the newly discovered Moabite Stone. By the* Rev. C. D. Ginsburg, *LL.D.*

The newly discovered Moabite stone discloses several important facts in the relation between the Moabites and the neighbouring nations which are material contributions to ethnology, geography, and palæography, in celebrating on this triumphal pillar the enfranchisement of Moab from the thraldom of Israel, by successive victories which Mesha, king of Moab, gained over Omri, king of Israel and his dynasty (*circa* B.C. 884); the new facts bearing upon these departments, therein exhibited, may be stated as follows:—

1. The Moabites were an independent nation from the reign of Solomon; they were resubjugated by Omri (B.C. 924), and Mesha regained the liberty of his country; and the land remained in the undisturbed possession of the Moabites up

* This paper, including a commentary on the inscription, has been printed separately *in extenso.*

to the time when the "Burden of Moab" was pronounced (Isaiah, xv., xvi.), B.C. 726.

2. In military prowess the Moabites under Mesha, whose country was not quite as large as the County of Huntingdon, were superior to the Jews. This is evident from the fact that the king of Israel was afraid to undertake the expedition against Moab alone, that he solicited and obtained the aid of Jehoshaphat, king of Judah, and of the king of Edom, that even these three allied armies, led by their respective sovereigns in person, dared not to confront the Moabite army in a straightforward invasion, and that they were ultimately completely driven out of the country. It is this victory which Mesha celebrates on the stone.

3. The ritual of the Moabites must have closely approximated that of the Jews; for the vessels of Jehovah were at once transferred from the sanctuary of the Jewish service to the temple of the Moabite deity (lines 17, 18). For other identical practices comp. line 17 with Numb. xxxi. 17, 18, 35, 40.

4. The Moabites were, moreover, superior to the Jews of that time in their architectural skill. Immediately after Mesha gained the victories over the three allied kings, he erected buildings which, as far as historical records are concerned, have no parallel in the Jewish annals. This is evident from the building of Korcha, with its parks, fortifications, towers, palaces, prisons, waterworks (lines 21 *b* to 26 *a*), the construction of the stupendous road across the Arnon (line 26), and many other structures erected in the single reign of Mesha.

5. Its geographical importance cannot be overrated. It not only specifies thirteen out of the twenty names of the places in Moab mentioned in the Bible,—viz. the Arnon (river), Aroer, Ataroth, Baal-meon, Beth Baal-meon, Beth Diblathaim, Bezer, Dibon, Horonaim, Jahaz, Medeba, Nebo, Kirjathaim,—but gives four new names of places, viz. Beth-Bamoth, Bikoran, Korcha, and Siran.

6. The language of the Moabites is almost identical with that of the Hebrews; indeed it has preserved forms and phrases which have gradually been eliminated from the Hebrew. Any one who can translate the Hebrew Pentateuch will be able to understand the inscription on the Moabite stone. The characters are the so-called Phœnician or Cadmean, and exhibit the primary source from which the original forms of the Greek alphabet are derived.

Anthropological Note on Carved Stones recently discovered in Nithdale, Scotland. *By* T. B. Grierson, *F.A.S.L.*

Among the finest specimens of ancient stone crosses that have been met with in the south of Scotland was one that had been found in Nithdale within the last twelve months; it was covered with carving, representing animals and other objects. Drawings were exhibited, and some of the ornamentation was very elaborate and beautiful. The stone cross, which is far from being perfect, when found was doomed to destruction; but it was fortunately rescued, and is now preserved at T. B. Grierson's Museum, Thornhill.

The Discovery of a Kitchen-midden at Ballycotton in County Cork. *By* Professor Harkness, *F.R.S.*

The author, after alluding to several kitchen-middens which have been discovered on the coasts of Ireland, described one which had recently been met with on the shore at Ballycotton in the County Cork. Here great quantities of the shells of *Purpura lapillus* occur, and in the soil beneath those shells, bones of ox, goat, and pig are found, the long bones of which have been broken for the marrow contained in them.

The sea has for several years been making great inroads on the coast at Ballycotton; and small knolls of peat, which rest upon the boulder-clay, are seen on the shore between high- and low-water marks. Near the base of these peat knolls bones of ox, goat, and pig are to be met with; and the long bones here have also been broken for the marrow. Associated with these are the bones of birds, which belong to the crane, not now indigenous to Ireland, and the wild swan.

A great thickness of peat formerly occupied a portion of the district which margins Ballycotton Bay on the west. This has, however, been in a great measure

removed for fuel, and the peat knolls are portions of the remains of this thick mass of peat.

The vegetable matter composing the peat knolls consisted principally of leaves of oak, alder, and hazle.

A considerable subsidence must have taken place in this portion of the coast of Ireland, as the remains of the food of man and leaves of land-plants are now found at a level considerably below that of the ordinary high tide.

Remark on the Anatomy of the Intellect. *By* WILLIAM HITCHMAN, *M.D.*

On some forms of Ancient Interment in County Antrim. *By* T. SINCLAIR HOLDEN, *M.D.*

On the Massagetæ and Sacæ. *By* H. H. HOWORTH.

The Chinese authors, translated by Stanislas Julien, and the 'History of the White Huns,' by Vivian St. Martin, were the author's chief authorities. These enabled him to identify the Massagetæ of Herodotus and the Greeks with the Ta Yetha of the Chinese writers and the Sacæ with the Sai and Szu of the same authors and the Sahs and Sakas of the Indian Epics, and to arrive at the very probable conclusion that Massageta is the indigenous name of the tribes called Sacæ by the Persians; so that Massageta and Saca are in fact equivalent terms, and refer to at most mere branches of one race.

This race has been declared by several competent authorities to be Turanian or Arian; the Chinese writers enable him to describe it definitely as Thibetan. The Khiang or Thibetans were, before the supremacy of the Turks, the dominant race of central Asia. It is interesting to connect them with the subjects of Tomyris and the great enemies of Cyrus.

The evidence is overwhelming to show that the Massagetæ were the ancestors of the Indo-Scyths, who overran Bactria and destroyed the power of the Greeks in Asia. So that we may also, the author considers, correlate the subjects of Kadphises, the great restorer of Buddhism, with the Thibetan race; these facts, in his view, effectually disposing of the old notion that the Saxons had any thing to do with the Sacæ and the Massagetæ with the Goths. It also disposes of the more popular delusion that the Welsh are descended from the Cimmerians. Cimmerian (the Gimiri of the cuneiform inscriptions) is only a transcription of the name Saka, and is equivalent to it, one being the Semitic, the other the Arian name of the same race.

Pre-Turkish Frontagers of Persia. *By* H. H. HOWORTH.

In a previous paper the author connected the Massagetæ and Sacæ with the Khiang or Thibetan races, and, on the other hand, showed them to have been the ancestors of the Indo-Scyths, who overthrew Bactria and the influence of the Greeks in Asia. Continuing their history, we find that the Indo-Scyths were divided into five kingdoms, of which Kouei chang was the chief, and that about the year 16 A.D. Kouei chang destroyed the four other kingdoms, and became very celebrated. It is constantly referred to both by the Armenian and Persian authors. Its great heroes were Korsako (the Kadphises of numismatists) and Kanichka, who was the regenerator of Buddhism, and who introduced that creed into Thibet and China. Previously to his conversion his people had been sun-worshippers; and the author traced to them that form of Mithraism which was introduced at Rome by Pompey, and which he brought from Parthia.

On the decay of the power of Kouei chang the nomades on the Persian frontier are again found under the name of Yuetchi and Jatoi. V. St. Martin has identified them with the Haiathelah of the Persians and the Epthalitæ of the Greeks.

About the fourth century the Avarian Huns overran Transoxiana and the country as far as the Indus, and in the pages of Procopius, Priscus, and Cosmas the topographer, the nomades are called White Huns, and their country Hunnia. These

are the Huns and Avares of the Indian epics. They were simply Getæ led by a caste of Huns. Procopius describes them as very civilized and quite different to the European Huns. These White Huns the author identified with the Khazars.

Now the Khazars, there are very strong reasons for believing, were Circassians; therefore the Circassians are the lineal descendants of the Massagetæ of Herodotus. That they have a very large Thibetan element among them has long ago been shown by Mr. Hodgson, the best of all authorities on such a subject. This race genealogy clears up a great many difficulties in the ethnography of the Persian frontier.

On the Avares. *By* H. H. Howorth.

The Lesghian tribes of the Caucasus have not received the attention they deserve. One of them is called Chundsag, another Avar. Since the days of Klaproth it has been known that almost every name of a Hunnic and Avarian leader in ancient times is still found as a familiar name among the Avars, the Chundsags, &c. of Leghistan or Daghestan. The conclusion has, however, always been evaded that both Avars and Huns were neither more nor less than the ancestors of these Caucasian tribes, that they spoke the same language as the Lesghs in fact. The author believed this identification to be consistent with every fact we know of the Huns and Avares, and that it explained many difficulties.

Again, the Avares were the dominant race of Central Asia before the Turks; they were the conquerors of the Epthalitæ, who were thenceforward known as White Huns, and of the Hunnic invaders of India mentioned in the Indian epics.

De Guignes, in his 'History of the Huns,' and in an interesting essay in the 25th volume of the 'Transactions of the French Academy,' showed long ago that the Avares were the same people whom the Chinese call Jouan-Jouan. It did not suit his theory, however, to make the Huns and Avares the same people. He preferred to identify the Huns with the Hiongnou, who have been most conclusively shown to have been Turks by Klaproth, Remusat, and others. This identification is not trustworthy. Hun and Jouan-Jouan are so nearly alike in form that it seems impossible for every writer to have overlooked the fact that they are the same name; and yet, so far as the author knew, they have never been identified as such before. The Avares and the Huns were the same folk, as we know from the relation of Western writers. If the Avares were identical with the Jouan-Jouan, the Huns must have been so too. The author postponed the interesting questions that arise on this identification to his paper on the Huns, and concluded by giving a history of the Avar invasions from Byzantine, Chinese, and Eastern authorities, the latter made accessible by the labours of Stanislas Julien and Vivian St. Martin.

This paper will be printed at length in the 'Ethnological Journal.'

On the Racial Aspects of Music. *By* J. Kaines, *F.A.S.L.*

The author, in a very brief glance at the characters of the music of the various races of men on the globe, drew particular attention to a striking anthropological fact; namely, that the music of the peoples of the north-west of Europe, unlike that of all the rest, was pervaded by a settled melancholy. He sought to account for this phenomenon physically and psychically. He drew attention to the climatal and general physical conditions under which the peoples of the north-west of Europe live, and suggested that, in the constant war with Nature, and the endeavour to modify Nature's laws, they acquired a gravity, awe, and sadness, of which the peoples of the sunny south knew nothing, as their music showed, Nature having used them more kindly. The author contrasted the biographies (as well as the music) of the German and Italian composers, and showed that the men differed as widely; sadness and sorrow marking the one, brightness and gladness characterizing the other. He commented upon the introspectiveness of the northern peoples, and the rapt attention and morbid analysis they give to the great problems of Life, Death, God, and Immortality; and stated that the contemplation of these and such sublime mysteries saddened and brightened by turns all their thoughts and impressions. It was curious to note that even the dance-tunes and popular airs of the

Germans, Norwegians, and Swiss (as has been remarked by Mr. H. F. Chorley, the eminent musical critic) were in a minor key. "Joyousness," continued the author, "is a plant that does not flourish in the bleak north. It flowers and blossoms perennially in the south, because there the air is balmy and soft. There the skies are always bright, and beneath man's feet the earth is fruitful though untilled. There Nature uses her children kindly, and even 'prepares for them a table in the wilderness.'" The author remarked incidentally that not music only, but the other arts of expression (architecture, sculpture, and the mythologies of the north of Europe) were imbued by the same melancholy spirit. He concluded by a few observations on the character of ancient Roman, modern Anglican, and dissenting Church music.

The Manx of the Isle of Man. By RICHARD KING, *M.D., F.E.S.*

The habitat of the Manx is the Isle of Man, and is situated in St. George's Channel, at nearly an equal distance from the shores of England, Ireland, and Scotland. It is remarkable that so near home we should know so little of the Manx.

The manufactures of the island, with which the Manx have little or nothing to do, are inconsiderable; but the principal source of its wealth, due to the Manx, is the Herring-fishery, which brings in a return of upwards of £60,000 per annum. More than 600 Manx boats are engaged in the Herring-, Cod-, and Ling-fisheries, employing 3800 men and boys, and 3600 square yards of netting.

The Manx are robust, frank, hospitable, and enterprising, and, in common with all the Celtic races, excessively superstitious. The language of the Manx is one of the six Celtic dialects which philologists have shown to belong to the class of Indo-European languages, and which are divided into high and low, the high being the Welsh, Cornish, and Armorican, the low being the Erse division, or the Gaelic, Irish, and Manx. As a spoken language the Manx is not unlikely to die out in another generation, being rarely used in conversation except amongst the peasantry. In most of the parish churches tweny-five years ago it was used three Sundays out of four, but it is now entirely discontinued.

The insular banks issue one pound and five pound notes. These notes are secured by guarantees on land deposited in the Roll's Office. The currency of the Isle of Man is now assimilated to that of England. The copper coinage has impressed on the reverse the arms of the island—three armed legs and the motto "Quocunque jeceris stabit." This device, which was the ancient symbol of Trinacria or Sicily, according to some authors, was introduced into the island by the Normans, according to others by Alexander the Third, King of Scotland; still it is a question whether the Manx did not originate the ancient symbol of three legs.

The zoology of the Isle of Man hardly if at all differs from that of the surrounding countries. The animal which attracts the attention of zoologists is the Manx Cat, the Stubbin or Rumpy, a tailless variety of the common Cat, *Felis catus.* Tradition asserts that the species was introduced at the time of the destruction of the Spanish Armada. According to Train, the Manx Rumpy resembles somewhat in appearance the cats said by Sir Stamford Raffles to be peculiar to the Malayan archipelago. They are best seen in a wild state, when the caudal vertebræ are entirely wanting; but by admixture with the common cat they are found with tails of all lengths. Tailless poultry are also common on the isle. The probability is, therefore, that the tailless cat and tailless poultry are peculiar to the Isle of Man.

On the Builders of the Megalithic Monuments in Britain.
By DR. A. S. LEWIS.

The author divided the inhabitants of Britain into three groups—the Kymric, long-headed, dark-haired, and light-eyed; the Iberian, dark-eyed and dark-haired; and the Teutonic, round-headed, light-haired, and light-eyed. He controverted the idea that the Iberians were the original race, and that they were exclusively the builders of the megalithic monuments which were found all over Britain; while the Iberians were found in much smaller numbers in the north than in the south of

Britain. The author attributed the megalithic monuments to both the Kymric and Iberian divisions of the great Celtic race, and supported his views by a careful consideration of the statistics of the physical characteristics of the inhabitants of Great Britain collected by Dr. Beddoe, President of the Anthropological Society of London, concluding by an appeal to those interested in the science to collect further statistics.

Remarks on Stone Implements from Western Africa. *By* Sir John Lubbock, *Bart., M.P., F.R.S.*

Considering that at the present moment Africa is probably the most backward in civilization of all the great continents, it is somewhat remarkable how deficient it is in stone weapons; that being, no doubt, owing to the great abundance of sands containing iron, and the facility with which that metal is obtained. This infrequency and almost entire absence of stone implements has been alluded to on various occasions by those who have felt it to be a difficulty with respect to the theory that the use of stone in all cases preceded the use of iron and other metals. But although implements of stone are of rare occurrence in Africa, still they are by no means altogether unknown. The first stone implements from the Cape of Good Hope we owe to Mr. Busk. Others have been discovered by Mr. Dale, the Inspector of Education in Cape Colony; and they are remarkably similar to the flakes and spear-heads which are found in Europe and elsewhere. In Egypt, also, stone weapons of a very simple character have been found; but from Southern Africa nothing has yet been received that could be called an arrow-head. Sometimes small stone implements are called arrows which are really not worthy of the name. The truth is that a savage is very careful indeed in the manner in which he manufactures his arrow-heads. It has probably taken him a day, or a day and a half, to get near his game; and it would be very provoking to him to miss his aim from any deficiency in the form of his weapon. It is therefore great economy of time on his part to devote a considerable portion of it to the manufacture of arrows which will be tolerably true. Therefore perhaps scarcely sufficient caution is used in calling small stone implements arrow-heads. Again, a very common type of stone implement found in Europe, the scraper, does not appear to be abundant in Africa. Sir John exhibited a specimen from the Cape of Good Hope, which he said was the nearest approach to the type which has come from that part of the world without being at all a typical specimen. Stone implements of rough flint have also been found in Mount Sinai, and a specimen was shown, found by Mr. Freeman, at Wady Ithm, in the Syrian district, on the road to Petra. But the specimens to which Sir John principally desired to call attention were some which have been sent over by Mr. Reade from Western Africa, that gentleman being engaged in scientific research in Africa at the expense of an enlightened merchant, Mr. Swanzy. It is true that implements of this character have been sent to Europe before, but they were very few, and did not attract much notice. Those now exhibited were obtained at some feet underground, in sections exposed by the river near Accra. There are several interesting points in Mr. Reade's letter, which accompanied them, one being the idea that these stones are thunderbolts. We know that is a notion which exists almost all over the world—from Western Europe to the far distant regions of Hindostan. That they may be employed as charms, and also as medicine, is a very general notion. Neither the depth at which these stones were found or the superstitious notions connected with them can be taken as evidence that they were of great antiquity. One of the axes from the African collection was put in contrast with a tray of other axes from all parts of the world, in order that attention might be called to the extreme similarity of these primitive implements. There were examples from New Zealand, North America, Chili, English, Irish, and German specimens, from Spain, British Guiana, South America, from the river Amazon, and from Australia. That common type, therefore, may truly be said to be found all over the world. Besides the ordinary type, there was a wedge-shaped, thick and very rounded form, not so widely distributed. The collection contained also a quartz-pebble, which had a hole carefully drilled through it, and had been used probably as an ornament. Considering the abundance of ores of iron in this African

district, and the facility with which they could be smelted and metal obtained, Sir John thought it probable that these stone axes belong to a time before the natives of this place became acquainted with the art of smelting iron.

On a recent Examination of British Tumuli and Monuments in the Hebrides and on the Western Coast of Scotland, with suggestive Inferences. By J. S. Phené, *F.G.S., F.R.G.S., Member of the British Archæological Association.*

The object with which the investigations had been conducted was the observance of natural physical circumstances of position in conjunction with the oldest archæological remains; more especially where the author had been so fortunate as to meet with undisturbed relics of prehistoric art. The first object of interest to which he directed attention was the tumulus in the larger Cumbrae, in the Firth of Clyde, of the different parts of which photographs were exhibited. It contained five stone cists, each formed of four slabs of red sandstone, with a large overlying slab for a cover. Within the cists was a layer of fine white pebbles. The cists were in an apparently studied position, the largest being placed nearly north and south, and on each side one of smaller dimensions tending towards the east and west; the two latter contained bones apparently burnt, with an incinerary urn of one of the oldest types of British pottery in each. To the rear of the first was a small cist containing the skull and bones of a child, and on the western side of that one in which there were no remains. The first and largest cist contained the bones of a large man. In the small cist, with the bones of a child, were portions of a broken urn, and in the western one a clean and empty urn only. There was a uniformity about the whole mound which pointed clearly to the cists being of one date, and that they represented one funereal operation. By the permission of the Earl of Glasgow, he made a cutting through the tumulus, and found abundant proof that the mound had been raised by art.

The position of the remains—the principal tomb having on each side one with evidences of cremation, of persons, as the bones indicated, of less stature than the occupant of the central cist, and therefore probably of women; that of the youth at the rear, and the presence of the empty cist or cenotaph—suggested the idea, admitted by Dr. Wilson in his 'Prehistoric Annals of Scotland,' of the custom of immolation on the death of a chief or archpriest.

The next object to which the author called attention was a tumulus at the northern end of Cantire, which is still under investigation, in which was discovered an urn similar in design to the principal one from Cumbrae. Like results had attended his researches in the vicinity of Cuff Hill in Ayrshire, of Berigonium in Argyleshire, and in the island of Arran; in each case pottery of the same type was discovered.

Referring to the archæological indications, a similar repetition of memorials occurred again in the direction of the Crinan Canal. Other discoveries were referred to by the author, who stated that on the western coast and islands up to Durness, by Cape Wrath, indications of a Pagan race were to be found; not the least remarkable amongst which were some specimens of serpent mounds and constructions, identical with those of Ohio and Wisconsin. His investigations had so far terminated at the remarkable cruciform temple in the island of Lewis, which he considered displayed striking indications of astronomical arrangement.

Contents of the Cumbrae tumulus, from examinations by Professor Allen Thomson *and* Dr. Young, *of the University of Glasgow.*

Centre Tomb.

Right femur, $18\frac{1}{4}$ inches long, but wanting the head; with this it might be $19\frac{1}{2}$ inches. Adherent calcareous matter near the lower end. Adult male.

Portion of the lower jaw of a man, near the chin on the right side, containing the canine, two premolar, and the anterior molar teeth; the first three only slightly worn, but the anterior molar worn down flat into the dentine. The sockets of the middle molar and the outer incisor broken through; the mental angle very prominent. A remarkably strong jaw, $1\frac{3}{4}$ inch deep to the point of the canine tooth.

North Tomb.'

Anterior permanent molar of the two sides.

Posterior or large infantile molar of one side.

Upper half of the parietal bone. All of a child of about four or five years of age.

S.E. Tomb.

A large number of fragments of bones, probably of the human adult, viz.:—

Upper border of the right orbit, part of malar, small part of superior maxillary, fragments of the parietal and other tabular bones of the cranium.

Parts of several dorsal and lumbar vertebræ.

Fragment of the sacrum.

Very numerous small fragments of the long bones, especially of the femur, tibia, and fibula; small part of an upper rib.

Some bones or fragments of the tarsus.

There are to be remarked conchoidal fractures across the compact parts of the shafts of the long bones, and frequently also longitudinal fissures externally.

S.W. Tomb.

Numerous fragments of the bones of an adult, apparently not of large size.

Parts of the pterygoid process of the skull, part of the mastoid bone, and tabular bones of the skull.

Processus dentatus and portion of the axis vertebra.

Fragments of the long bones, viz. femur, humerus, radius, ulna, tibia, fibula.

Fragment of the ischium (?).

On a Flint-flake Core found in the Upper Valley-gravel at Salford, Manchester. By JOHN PLANT, *F.G.S.*

The rivers Irwell and Mersey, from Manchester to Liverpool, flow down a wide valley, eroded through beds of Keuper or Bunter sandstone. The present river-bed is of moderate width to Runcorn-gap, below which it becomes a wide estuary. In earlier times this estuarine character may have extended inland even to Manchester, for wide tracks of gravels, sands, and silt spread away from the river banks on either side; under these lie the Boulder-clays and sands of the Postpleiocene or glacial drifts. The oldest sands and gravels of estuarine origin lie the highest and most distant from the river, except over places where the Bunter beds crop out in high banks, in some places 200 feet above and a mile beyond the river; and from these beds are a series of well-marked river-terraces, dropping inwards towards the river. These are composed of old alluvium with smooth, flattened, and iron-stained pebbles in layers of sand and fine silt. The lowest terrace is meadow land, at times deeply flooded, and receiving new layers of silt. In the great flood of November 1866 three inches were deposited in twenty-four hours. The oldest sands and gravels may possibly be related to the age of the high-level gravels of the river Somme, and to the flint-weapon gravels of the south-east of England. Lancashire is a county almost devoid of flints, either natural or artificial; and thus weapons of the palæolithic age are altogether absent from its drifts, and not more than a score of weapons of the neolithic age have been to the present discovered in its drifts and cave-deposits. These later stone weapons are also poor in make, and have no racial peculiarities. The only exception of a weapon with palæolithic features is the one now described, which fortunately was taken from the bed of drift in my presence, July 1869. It was lying in a four-feet bed of laminated sandy silt, under six feet of river-gravel and yellow clay, with rough gravels and the boulder-clays below. The excavation was near the Ordsall Lane railway-station, about 1000 feet from the banks of the river, and nearly 108 feet above the river level, the average level of the middle terrace higher up the valley. The deposit where the flint-core lay probably represents the age of the river when it flowed over the middle terrace. The flint-core bears the size and shape of a horse's hoof; from the front curved face five fine flakes have been struck, and smaller ones from other parts. The original surface is shown in three places, and encrustations derived from the soil adhere very firmly on the fractured parts, supplying a strong proof that, whatever may have been its origin, it had long lain in its bed under the river-gravels.

On a Wooden Implement found in Bidston Moss, near Birkenhead.
By CHARLES RICKETTS, *M.D., F.G.S.*

On certain remarkable Earthworks at Wainfleet, in Lincolnshire.
By the Rev. C. SEWELL, *M.A.*

These works consist of a series of mounds, about forty yards long and twelve feet high, lying parallel to the sea front, which is now two miles from them, but which in Roman times came close up to them. A Roman sea bank runs along their face, and appears to take its shape from the contour of their front. The Roman station of Vanonia, according to Camden and Stuckley, lies about a mile to their rear. Traces of these mounds can be discovered over a mile and a half of ground. At the north and south ends they have been much mutilated. A central piece, about 300 yards long, remains entire. This block of mounds is divided into five separate groups, the divisions between them being marked by narrow watercourses running at right angles to the general direction of the mounds, and terminating in well-marked regular depressions, which, on the supposition of this being the site of dwellings, might have been freshwater-tanks. The mounds at this point extend backwards from the ancient shore-line a space of 400 yards, standing, with little interval between them, one behind the other, as many as twelve or fourteen in number.

No traces of remains or human handiwork have been observed in these mounds, though they are being constantly dug down and removed for one purpose or another. They are composed of the soil on which they stand, though there is an account that some of them are of a black peaty soil, which, however, can be found within a short distance. No mention has been made of these mounds either by Camden or by Dugdale in his 'History of Draining,' which treats largely of this neighbourhood; but their antiquity is undoubted, if only on the evidence of their local name—the Hilly Tofts. The popular account of their use is that they are the remains of ancient salt-works, though the method by which salt was made upon them by evaporation of sea-water is not very clearly made out. If this theory of their use be the true one, they are interesting as being probably the source of supply of salt to the Roman settlements all along the east of England. Another theory is that the mounds are to be connected with the Danish invasions of England. It is a plausible suggestion, but founded on no evidence, that the hollows between the mounds were used as places to lay up the Danish ships while their crews made their advance inland. The name *Tofts* points to some connexion with Danish occupiers; but if that name really indicates "an inhabited spot," the Danes, whether they used the mounds as dry docks or not, may have found them occupied by human dwellings. In spite, therefore, of all absence of remains, it is possible that we have here the site of an ancient British fen-village, raised on mounds, as the Swiss lake-dwellings were on piles, above the watery waste around them.

On the Use of Opium among the Chinese. *By* G. THIN, *M.D.*

The Mental Characteristics of the Australian Aborigines.
By C. STANILAND WAKE, *Dir. A.S.L.*

The chief inference to be drawn from the mental characters exhibited by the aborigines of Australia is that they are children whose intellect has, by the exigencies of their situation, been continually exercised, and therefore become more than ordinarily keen and active, while the moral nature has remained almost wholly in abeyance. From the data furnished by the paper, it is evident that the Australian aborigines occupy the lowest position in the scale of humanity, and that they show what must have been the condition of mankind in primeval times.

The Physical Characters of the Australian Aborigines.
By C. STANILAND WAKE, *Dir. A.S.L.*

The most striking peculiarities presented by the external physical characters of the

aborigines of Australia are:—the great prominence of the brow, associated, among some tribes, with shortness of the lower jaw; the wide expansion of the nostrils, combined with great depression of the nose at the base; the extreme width of the mouth; the absence, sometimes observable, of any difference between the incisor and canine teeth; the straightness and silkiness of the hair, except among certain tribes in the north and north-west; and the hairiness of the entire body, which is a phenomenon apparently not uncommon.

On an Implement of Quartz from St. George's Sound. *By* HENRY WOODWARD, *F.G.S., F.Z.S.*

The author drew attention to a crystal of quartz, having its terminal planes preserved at both ends, which was found by his colleague Mr. Thomas Davies among a number of other minerals in the British Museum forming part of the old Sloane collection.

The interest attaching to the specimen is of two kinds: it is, first, of historic interest, for upon close examination there was found inscribed upon it in ink (in Capt. Cook's writing), "St. George's Sound, N.W. coast of America: Capt. Cook," thus proving it to have been brought home by that illustrious explorer; and, secondly, it is of prehistoric interest, for the crystal had been employed to bore or pick holes in the ice by the Esquimaux, as proved by the notches made in its sides for fixing it securely in some handle of wood. Such implements are used at the present day by the Esquimaux to bore holes in the ice to catch fish in winter.

GEOGRAPHY.

Address by Sir RODERICK IMPEY MURCHISON, *Bart., K.C.B., D.C.L., LL.D., F.R.S., F.G.S., President of the Section.*

WHILST wars have from time to time changed the political geography of foreign states, we, who happily live in our sea-girt isle, possess frontiers which for many long years have been preserved intact; and now that we meet again, for the third time, in this rich and enterprising seat of commerce, we may tranquilly take note of any changes which may have been lately made in the boundaries of other kingdoms. But such changes in political geography, though specially to be delineated on maps, need scarcely occupy attention at a Meeting of the British Association, and we may hand them over to the politician. Our chief duties are to receive and discuss all communications which reveal to us new discoveries in Physical Geography and the affiliated branches of Science in all parts of the globe.

This Section E had for many years the title of Geography and Ethnology; but the latter term has recently been abstracted from us, Ethnology having been relegated to the newly constituted comprehensive Section of Biology. Now, although I have often presided over this Section when it possessed its double title, I admit the value of the change, seeing that we are relieved from the duty of receiving and discussing those anthropological memoirs which are intimately connected with physiology and comparative anatomy. Such memoirs could not be adequately discussed by geographers, and they are now submitted to competent judges. At the same time I earnestly hope that papers relating to Ethnography, including accounts of the language and customs of distant peoples, and which is intimately bound up with the physical geography of countries, will, as heretofore, flow into our hall, and thus render our meetings on this occasion as successful and popular as they have been during past years. In the course of the present Meeting a paper will be read from that distinguished geographer Colonel Yule, which precisely illustrates my meaning. It is on the analogies of manners between the Indo-Chinese races and the races of the Indian archipelago; and is exclusively written for our Section by its learned author, who expresses, as you will learn, his astonishment that such

subjects, so inseparably connected with Geography, should ever be severed from it in the proceedings of the British Association.

Geography in a broad sense is so closely allied to many researches, that, since the foundation of the British Association, it has at times been coupled with different sciences by our legislators. At first it was very naturally grouped with my own peculiar subject, Geology, which may well be termed the Comparative Physical Geography of byegone ages. But this union did not last long, because my brethren of the hammer, ever producing more memoirs than could be discussed at any one Meeting, the Geographers, who were desirous of having much time and attention allotted to themselves, withdrew and no longer took part in Section C.

In those days Geography could not find a separate place in the list of sections; for it was a canon in the constitution of the British Association, that the number of sections was to be for ever limited to seven. But as time wore on, changes, of necessity, occurred. The first of these took place in Section B, which began by including Chemistry and Agriculture. But this connexion of a pure Science with the practical objects of proprietors and farmers could not be permanent; and the cultivators of the soil (finding no space for their exhibitions, and taking the British Association as a model) established that most important national body, the Royal Agricultural Society.

Next the medical men, finding that no adequate justice could be done in one section to their diversified subjects, separated from us, and at the suggestion of my lamented friend Sir Charles Hastings, founded the great Medical Association of Britain.

Through this withdrawal of medical science, the Section denoted by the letter E remained for some time a blank, without any scientific duties attached to it; and it was only in the year 1851 that, on my own suggestion, and at the Ipswich Meeting, the blank Section was refilled under the title of Geography and Ethnology. Under this title I have read addresses to the Section at Leeds in 1858, at Oxford in 1860, at Newcastle-on-Tyne in 1863, and at Bath in 1864.

In alluding to such written addresses, it is well to remind the younger members of our body that during twenty-five years they formed no part of our Proceedings. These preludes to the business of each Section were for the first time introduced in the year 1856, and the person who led the way in these useful and now necessary parts of our duties was the present Earl of Derby, who then, as Lord Stanley, presided over the Statistical Section at Cheltenham. I cannot advert to this fact, so highly creditable to my noble friend, who is now a Vice-President of our whole body, without reminding you that his illustrious father, whose name will ever be revered in British history, and whose beneficent deeds will ever be gratefully remembered in Lancashire, was himself an admirer and patron of geographical explorers, and a Fellow of the Society over which I preside. I refer you to my last Anniversary Address to the members of the Royal Geographical Society for the expression of my admiration of his character.

Before I speak of some few of the contributions which will, I trust, be brought under our consideration, let me glance at the rapid progress of discovery in recent years, and, first of all, at the great and important additions to pure Geography which have been made in Central Asia both by Russian and British explorers.

With all the western portion of that vast region in which lie the Khanats of Khiva, Bokhara, and Khokan, some of you may now be acquainted, through the accounts of Russian observers, who have already fixed the correct positions of the chief towns, mountains, and rivers of Western Turkistan. Proceeding eastwards from the Sea of Aral, the Russians have, for the first time in history, rendered the River Syr Daria (the Jaxartes of Alexander the Great) navigable by steam-vessels of a limited size, and fixing military posts on its banks, have ascended towards its sources and taken possession of the populous and flourishing city of Tashkent, a great mart of caravan commerce.

Again, Russia has triumphed over the Khan of Bokhara, the savage ruler who in years gone by barbarously put to death two British officers, Stoddart and Conolly, and who has now met with a due humiliation. As peace has been concluded between the Emperor of Russia and those turbulent chiefs, who have now been rendered subordinate to a great civilized nation, we may hope that the

blessings of commerce will restore this fine region to some portion, at least, of the wealth and dignity which it held in those ages when its monarchs ruled over nearly one-half of the then civilized world. The crude and ill-founded apprehensions which once existed that these advances of Russia would prove highly prejudical to British India, have, through due reflection, entirely evaporated from among British statesmen, who are now convinced that it is much better for the commerce and peace of both nations that intermediate warring chiefs should be kept under by a strong power. After all, between the great territories of Russian Turkistan and those of British India, there lies the long, broad, and mountainous region of Affghanistan, with whose present ruler we are on good terms.

But what about Eastern Turkistan? some of my hearers may say; what about those enormous tracts which lie immediately to the north of the north-western mountains of British India, the Himalayas, and Cashmere? The answer which I have given in my last Address to the Royal Geographical Society is the most satisfactory explanation which can be offered, and I here give the pith of it. The Russians have not advanced beyond the chain of the Thian Chan into any part of those territories in which the cities of Kashgar, Yarkand, and others are situated. These countries, which until a few years ago were held by the Chinese, and are inserted in all old maps as an integral part of the Chinese empire, have entirely extirpated their conquerors, and the mass of the natives, being Mahommedans, are now under the rule of a brave soldier of their own faith, who, under the title of the Ataligh Ghazee, or Leader of the Faithful, has brought the people into a state of perfect order, after having been in the most tumultuous and insurrectionary state so long as the Chinese vainly attempted to govern them.

The process by which an intercourse has been established between this Eastern Turkistan and British India has been so eminently characteristic of the efforts of a powerful trading nation like our own, that a very brief account of it may be acceptable to some of my hearers in this great mart of commerce. Tea-plantations having been successfully cultivated by our countrymen upon the southern and lower slopes of the Himalayan Mountains, it occurred to a most able British civilian, Mr. Douglas Forsyth, who was diplomatically employed in Cashmere, that the population of Eastern Turkistan having been so long accustomed to drink tea, and having been entirely deprived of it since all intercourse with China had ceased, would gladly hail the reappearance of their favourite beverage, if a supply could be brought to them from the south. Mr. Forsyth accordingly sent a small sample (a horse-load only) of tea across the mountains, as a present to the great ruler of this new kingdom. As this present was "gratefully received," one of our British tea-cultivators at Kangra, Mr. Shaw, resolved to face all the difficulties of a passage through the lofty mountains of the Karakorum and Kuen Lun; and, fitting out a caravan bearing tea, he conducted it himself in safety by Yarkand to Kashgar, where he was well received by the Ataligh Ghazee. At first, indeed, things looked unpropitious, for Mr. Shaw was proceeding fairly and simply as a British merchant, when there arrived just at the same time a warlike-looking Englishman. This was Mr. Hayward, late of the 72nd Regiment; and for a time both were placed *en surveillance*, but most amicably treated. In fact Mr. Hayward had been sent out by the Royal Geographical Society to explore, if possible, that great desert plateau, the Pamir Land, occupied entirely by nomade Kirghis, in which the rivers Oxus and Zerafshan have their rise; but being unable to force his way thither through certain disturbed tracts to the north-west of the Punjaub, he took a route which led him to Yarkand. The arrival of the two Englishmen, which at first seemed so unintelligible and suspicious, turned out to be in the end most advantageous to all parties concerned; for Mr. Hayward had it in his power to fix the latitude and longitude of places never before visited by a geographer, whilst Mr. Shaw, *dona ferens*, gratified the Ataligh Ghazee not only by his manners and address, but particularly his packages of tea. After a year's sojourn at Kashgar and Yarkand, in Eastern Turkistan, Mr. Shaw returned to British India, and the Viceroy, the Earl of Mayo, seeing the prospect of establishing a profitable alliance with this new sovereign, his Excellency not only received an envoy sent by the Ataligh Ghazee to his Excellency and the Queen, but has recently sent a special British mission to that great chief; and for this important mission he has wisely

selected Mr. Douglas Forsyth and Mr. Shaw, as negotiators in the establishment of a treaty of commerce between the respective countries; a letter from Mr. Forsyth to myself, written on the eve of his departure from Ladak, on the 2nd of July last, and containing matter of great geographical interest, will be read in the course of this meeting. It will be seen by this letter that, grand as are the geographical discoveries made Captain Montgomerie and his pundits, a grander and richer field than any yet described seems now to invite exploration. I may add that I have received a letter from the Earl of Mayo, dated the 18th of July last, in which he speaks hopefully of this important mission.

On our part, we have thus opened out a market for our Indian teas, and also for many articles of British manufacture, in exchange for which we shall receive not only specie, but also the fine silks and wools of Turkistan, and many mineral products of those mountains, some of the peaks of which rise to upwards of 24,000 feet, and many of whose level tracts and plateaus are 14,000 to 17,000 feet above the sea. To obtain a full insight into the nature of this hitherto unknown region and its remarkable ruler, I refer you to an admirably clear and telling memoir by Mr. Shaw, published in the 'Proceedings of the Royal Geographical Society,' June 7, 1870.

In making these observations, I would invite some of the enterprising merchants of Liverpool, Manchester, and other places in this flourishing county of Lancaster to transmit to Yarkand, viâ Bombay and the Punjaub, some of their gayest but stoutest cloths and cottons; and I venture to prophesy that the Turkistan people will rejoice in the arrival at the remote Yarkand of such British goods, for which they will gladly exchange the products of their own country or pay in specie.

But, to return to Geography, Mr. Hayward, nothing daunted by his first failure, is now endeavouring to explore the mysterious Pamir Land, which no European has ever yet traversed, though Lieutenant Wood of the Indian Navy did, many years ago, reach one extremity of it in an endeavour to determine the source of the Oxus, as recorded in the tenth volume of the 'Journal of the Royal Geographical Society.' I earnestly hope that Mr. Hayward will be the first geographer who will have described this lofty region, which the natives term, in their Eastern style, "The Upper Floor of the World." If he should traverse the Pamir Land, I have learned, by correspondence with the Russian Imperial Geographical Society, that our countryman will then have a free passage granted to him through all Russian Turkistan. It is thus that our Science makes its cultivators of every nation as kindly and considerate to each other as Freemasons. Let me add that the Royal Geographical Society has awarded its Founder's Gold Medal to this brave and energetic man; and we fervently hope that he will come home through Russia before next year, to receive his well-merited reward.

Deep-Sea Soundings.—The remarkable additions to Geographical and Natural-History knowledge which have been made of late years by sounding and dredging at great depths in the ocean, have excited the liveliest interest. The attention of modern geographers was long ago directed to this subject by Parry, James Ross, and Captain Denham, R.N. The last of these measured downwards in the ocean, between South America and the Cape of Good Hope, to the great depth of 7706 fathoms, and thus enabled geographers to realize the aphorism of Alexander Humboldt—that the greatest depths of the sea would be found to be at least equal to the height of the loftiest mountains. Subsequently Dr. Wallich, who ably served as the naturalist on board the 'Bulldog,' commanded by Sir Leopold M'Clintock, enunciated the then novel and surprising truth that certain marine animals (including starfish) lived at the depth of 1260 fathoms, and even preserved their colours when brought to the surface.

More recently the scientific explorations of the deep sea to the north and west of the British Isles, as conducted by Dr. W. Carpenter, Mr. J. Gwyn Jeffreys, and Professor Wyville Thomson, have thrown much new light on this attractive subject. They have vastly extended our acquaintance with many submarine data, including the temperature of the sea at various depths, and have proved that currents of different temperatures (each containing a characteristic *fauna*) are running, as it were, alongside of each other, or in contiguity, beneath the surface of the sea.

These data, and a consideration of the various species of marine animals which were found, are supposed to have had such material bearings on geological science, that it would be a dereliction of my duty as an old geologist if I were not to endeavour to disentangle the unquestionably true, novel, and even startling facts which these researches have made known, from one of those speculations which the eminent leader of this expedition has connected with them, and which, if acquiesced in, might seriously affect the inductions and belief of practical geologists.

Dr. W. Carpenter, in a lecture given in the Royal Institution, in summing up his views as to the effects of the discoveries then made, thus spoke:—"The facts which I have brought before you, yet still more the speculations which I have ventured to connect with them, may seem to unsettle much that has been generally accredited to geological science, and thus to diminish rather than to augment our stock of positive knowledge; but this is the necessary result of the introduction of a *new idea* into any department of scientific inquiry"*.

To this statement I beg to demur. Sound practical geologists, whether they be Uniformitarians, Catastrophists, or Evolutionists, like the great Naturalist who now worthily presides over the British Association, are all agreed in the fundamental truths of this science as established by positive readings in the stone-books of Nature. They are confident that undeniable proofs exist of an enormous succession of deposits, which have been accumulated under the seas of former periods, in each of which the physical geography of our planet, and with it the orders of animals and plants, were very dissimilar from each other, and also differ still more, as we examine backwards to the earlier deposits, from those of the present day. We believe, upon the evidences presented to us, and, irrespective of all theory, that the vast accumulations under the seas of those periods have had their relations to each other thoroughly and conclusively established by a clear order of superposition. We further believe that the deposits so relatively placed contain, each of them, organic remains, which are, in great measure, peculiar to the one great group of strata which they occupy.

With these indisputable proofs of geological succession as established by clear superposition of the formations, and the distinctive fossil characters of each, I necessarily dissent from the suggestions of Dr. Carpenter and other naturalists, that, inasmuch as the present deep-sea bottoms contain abundance of *Globigerinæ*, with such animals as *Terebratulidæ*, both of which differ little from the forms found fossil in the chalk formation, it may be inferred in a broad sense that we are still in the Cretaceous period.

May we not, indeed, by a similar bold hypothesis, affirm that we still live in the older Silurian period? for, albeit no bony fishes then existed, many *Globigerinæ* and creatures of the lowest organization have been found in these old rocks and associated with *Terebratulidæ* and *Lingulæ*, the generic forms of which still live.

Revering, as I do, those great naturalists who have shown abundant proofs of the progress of creation, or, as others term it, of evolution, I hold to my opinion, matured by a long experience, whilst I dissent from the inferences of my friends Dr. W. Carpenter and Professor Wyville Thomson, that the recent discoveries may, or can, unsettle much which has been accredited to what I call sound geological history, as established on absolute observations and separated from all theory.

The new ideas which have been introduced by the meritorious labours of Carpenter and his associates do not, as he has suggested, diminish the amount of positive knowledge; on the contrary, they augment it, though they do not shake, in any way, the foundations of geological science. I willingly grant, however, that these new discoveries overthrow the theory that defines the depths in the sea at which certain groups of fossil animals must have lived.

Whilst on this topic, I rejoice that, at this Meeting, we are to be furnished with an excellent paper by my distinguished friend Captain Sherard Osborn, on the whole subject of Ocean Deep-sea Sounding as carried out by the Admiralty, and in which he will illustrate, by maps and sections, much of his own most energetic operations in reference to submarine telegraphy.

In connexion with the interesting subject of the geography of the ocean, I may call your attention to a little work of great merit which has lately appeared, under

* Lecture delivered at the Weekly Meeting of the Royal Institution, April 9, 1869.

the title of 'Physical Geography, in its Relation to the prevailing Winds and Currents,' by Mr. J. K. Laughton. A perusal of this book will show how wide is the field embraced by this important branch of geographical science, and at the same time how much yet remains to be done before we attain to a satisfactory knowledge of those great movements of the ocean and atmosphere included under the terms Gulf-stream, Equatorial current, Trade-winds, Monsoons, and so forth. Mr. Laughton, in the book to which I allude, has called in question the accuracy of the prevailing theories intended to explain these grand and, in some respects, complex phenomena. The received hypothesis with regard to the trade-winds, for example, first outlined by Halley towards the end of the seventeenth century, but developed by Hadley about fifty years later, and modified a few years ago by Maury, he shows to be quite inadequate to explain all the facts of the case. This hypothesis, as is well known, assumes that the lower strata of the atmosphere near the equator, being overheated by the sun's rays, expand and rise into the upper regions of the aërial envelope, their place being taken by a cooler air, which rushes from the higher latitudes of the north or south as the case may be; and, moreover, that the ascending heated air travels backwards, as an upper current, to the latitudes where the cool wind originates, and then, descending again, the aërial circulation is completed. One of the most striking objections made by Mr. Laughton to this explanation is, that the equatorial zone is far from being the hottest part of tropical and subtropical regions. He shows, as a matter of fact, in the North-Atlantic basin, that the Great Desert of Sahara has a temperature from 20 to 50 degrees hotter than the equatorial zone; yet, so far from a cool current of air being drawn in from the Atlantic towards this heated region, the north-east trades pass straight onward in their southerly course without the slightest indraught towards the African coast. He also shows that there is no proof of a vertical movement of the air at the equator, or in the latitudes where the upper currents are supposed to descend again. A multitude of similar or parallel instances are adduced from other parts of the earth; in fact nothing has more surprised me, in perusing the work, than the great amount of reading and research the author has applied to the elucidation of this and kindred problems.

Having shown the untenability of the received hypothesis, he modestly advances a new one of his own. This is difficult, perhaps, to explain in a brief manner; but he shows, from the most varied evidence, that the general movement of the atmosphere over the whole earth is from west to east, and that in regions where the prevailing winds at the earth's surface are not westerly, an upper and strong westerly movement exists above the lower winds. The trade-winds, monsoons, and all other partial atmospheric movements, he shows to be chiefly eddies and reflected currents of greater or less constancy; and he confirms this supposition by an exhaustive examination of the laws of movement of air and other fluids. I may say, in short, that even those who may not agree with the author's reasonings will find both pleasure and profit in studying the rich store of observation and lucid argument contained in this little work.

Among the many interesting papers which will be read before you during the present Meeting, I may announce two, on subjects of great general interest, by General Sir Henry Rawlinson—one on the Site of Paradise, and the other on the River Oxus; both the fruits of long study and research, and sure to be listened to with the attention that every thing emanating from so distinguished a geographer and philologist so well deserves. An important communication from Dr. George Campbell on the Physical Geography of British India is also expected, a subject which has been for years a special study of the author, during his residence in a high official position in India. Mr. T. T. Cooper, a traveller who has distinguished himself by his persevering endeavours to traverse the difficult country between Western China and our Indian possessions in Assam, will read a paper on Eastern Thibet, in which he will dilate on the commercial bearings of his explorations, which were undertaken with a view to discover a route for an overland trade between the populous and productive regions of the Yang-tsze-Kiang in China and the equally rich and densely populated plains of British India.

With regard to Africa (that great continent which still continues the principal field of geographical enterprise), I have to announce that Mr. Winwood Reade,

who has recently returned from an exploration undertaken under the auspices of the Royal Geographical Society, and at the cost of an enlightened merchant, Mr. Andrew Swanzy, will communicate to the Section an account of his hazardous journey to the Upper Waters of the Niger and to the Bouré country. Mr. Reade explored a portion of the Niger not previously visited by any European traveller, and opened up a tract of populous country, in which is situated the town of Farabana, containing 10,000 inhabitants, previously unknown to geographers.

In respect to those portions of Central America with which many readers have become acquainted through the descriptions of Stephens and Squier, I may inform you that you will be interested in a communication from Captain J. Carmichael upon countries occupied by the Indians of British Honduras and Yucatan. Ascribing an Eastern and probably an Egyptian origin to the earlier buildings and temples of the aboriginal American Indians and their idols, the author, who has explored the region he describes, and speaks their language, endeavours to throw additional light on the subject. He confesses, however, that in these mysterious monuments he finds as much difficulty in assigning them definitely to any race of men as British and other authors have had in fixing the origin of our own most ancient monuments at home, such as Stonehenge and other Druidical remains. He differs from Stephens and Squier and those authors who do not assign a great antiquity to these reliquiæ, and shows that when the Spaniards took possession of the country several of the colossal buildings and temples had even then a very antique appearance.

Captain Carmichael discusses with spirit the question of the former use of the huge and lofty tumuli which abound, and suggests the probability that many of the well-chiselled and beautifully formed stone buildings and ornaments were fashioned into their present shapes by stone implements only, all the arrow- and spear-heads which he found being made of obsidian. The Indian king of these parts had a palace at Quiché which, according to Torquemada, rivalled that of Montezuma in Mexico. The enthusiasm with which Captain Carmichael describes these old ruins will, I hope, secure the attention of the Section.

Two of our Secretaries, Mr. Clements Markham and Mr. Major, will communicate papers,—the first being an outline of an elaborate work he is preparing on the history and progress of all the surveys in India; the latter on the long debated question of the so-called Landfall of Columbus.

Governor William Gilpin, of Colorado, who has recently reached our shores from that grand central region of North America, will, I trust, favour us with a sketch of that rich, metalliferous, mountainous country, which ten years ago he thoroughly described, when he energetically advocated the execution of that gigantic railroad which now happily connects the Pacific and Atlantic Oceans*.

Geographical Education.—A strong desire on the part of the Council of the Royal Geographical Society to induce the heads of our public schools to promote the study of geography, on a plan prepared by Mr. Francis Galton, led us to offer annually two medals, to be competed for in an examination directed by the Society. It gratifies me to announce in this town that in the two years during which these honours have been distributed, the medals adjudicated each year have been won by young men in the public schools of Lancashire, viz. Liverpool College, and Rossall School, near Fleetwood.

When we consider that all the leading schools of the United Kingdom were invited to compete for these honours (and several of them did so compete), the fact which I have just mentioned does great honour to this prosperous mercantile county, which among its rising generation doubtless contains many a young aspirant to win the fame of Raleigh.

I may conclude this Address by dwelling for a few moments on the topics which, of all others, most interest myself, and I doubt not, the great majority of my countrymen—the explorations of inner Equatorial Africa by Sir Samuel Baker, and of Southern Africa by Dr. Livingstone.

Sir Samuel, being thoroughly well supported with those appliances which the

* See 'The Central Gold Region of North America; with some new views of its Physical Geography, and Observations on the Pacific Railroad.' By Colonel William Gilpin. Philadelphia and St. Louis, 1860.

Viceroy of Egypt has so liberally afforded him, will surely add largely to our acquaintance with the vast central and watery region on each side of the equator. A letter which he wrote to me from Khartoum in March 1870, stated that, having received in sections, on the backs of camels, all the vessels of his river and lake flotilla from England, as prepared by Mr. Samuda, he was full of hope and confident of success. Recently, I have received a longer and most interesting letter from him, which will be read at the present Meeting, and which graphically details the difficulties over which he has triumphed to the present time. We learn from this letter that Baker, starting from his station on the White Nile, in lat. 9° 26′, next November, can only reach Gondokoro much later than he anticipated: we have further to reflect upon the fact that after arriving at that place his great difficulties would commence; for, in the Bari country, peopled by negroes who have been rendered furious and wretched by cruel slave-dealers of various nations, he would also have to transport all his vessels and materials along the right bank of the Nile, where the great stream flows over granitic rapids. He has also to carry all his goods over the Assua River, a great tributary of the Nile, by a wire or chain bridge, which he had to construct. Having vanquished these obstacles, and having reached that portion of the Nile in which his vessels could be launched, he would then sail up the stream until he reached his own great lake, the Albert Nyanza. This accomplished, and cheered by his charming and devoted wife, he would be thoroughly master of a position wholly unprecedented in the history of African discovery *.

As I have already alluded to a very barbarous tract through which he would have to pass, and which was formerly traversed by Speke and Grant, I would observe that it is specially to such tracts that Baker holds instructions from the Khedive to extirpate the cruel slave-dealers who have brought about these horrors by the robbery of their ivory from the natives and the capture of women and children. I specially make this allusion, because a mistaken notion had arisen in Egypt that Sir Samuel proceeded on a mission to abolish slavery altogether. Now, as every Egyptian household contains slaves as their only domestic servants, we learnt from our Associate, Lord Houghton, when he visited the Suez Canal, that the Egyptians were much prejudiced against Sir Samuel. But no such Quixotic and, I might say, impossible task has been assigned to Baker, for domestic slavery is ingrained in all parts of Africa as a regular institution of the land. Atrocious and cruel slave-dealing and robbery may, however, be thoroughly put an end to; and this my friend has already commenced, through the agency of Egyptian soldiers. Of his energy in these philanthropic measures you will have a pregnant proof in the letter which will be read to you. In this way the poor African serf may be assured that when he sows his grain he will reap a crop at a future day.

I can well imagine the delight with which Baker will define with his flotilla the western boundary of his great lake, and delineate the course of those lofty mountains on its western shore which he had only seen at a great distance in his former journey. We may also picture to ourselves how he would rejoice in exploring wide tracts of that vast unknown interior in which large bodies of water lie, which are supposed to feed the Congo. The point of the compass, however, which will be first sought by the intrepid voyager will, I doubt not, be the southernmost end of the Albert Nyanza, because it is there that he hopes for the happiness of falling in with and relieving his great contemporary Livingstone.

If, indeed, that indomitable missionary, who unquestionably stands at the head of all African explorers, should succeed in tracing a connexion between the waters of the Tanganyika Lake, where he was when we last heard from him, and the south end of the Albert Nyanza, why then the meeting of these two remarkable men will be the happiest consummation of our wishes. And if that should be accomplished, Sir Samuel Baker himself will, I doubt not, cheerfully award the greater share of glory to his fellow explorer, who will then have proved himself to be the real discoverer of the ultimate southern sources of the Nile.

In waiting for the solution of this great problem I adhere, in the meantime, to the opinion which I previously expressed, that if Livingstone be still at or near

* I communicated an outline of Sir S. Baker's progress to 'The Times' of the 26th August.

Ujiji on the Lake Tanganyika, to which place supplies have been sent to him, he will at once proceed to determine that problem, and will not think of a return to England until the grand desideratum is carried out.

Judging, indeed, from his own original observations respecting the course of those rivers which take their rise in 8° to 9° S. lat., and believing as he did that most of them flow by the western side of Lake Tanganyika and do not enter that lake, it seems to follow that, in pursuing a N.N.-westerly direction, several of these waters must feed the Congo and so issue on the west coast. If such should prove to be the fact, why then this great traveller will have been the first to determine the true sources of both the Nile and the Congo.

And here I would ask why any one who knows what Livingstone has undergone should despair of his life simply because we have had no news from him during the last fifteen months? Did not much more than that period elapse whilst he was in the heart of Africa without our receiving a word of comfort respecting him? By the last accounts he was hospitably received by Arabs who are friendly to the Sultan of Zanzibar, who is Livingstone's patron and also a protector of the Negroes.

I had written thus far, and all was in type, when I received a letter from Dr. Kirk at Zanzibar, dated 29th June, 1870, which has comforted me exceedingly; for, sanguine as I have been as to the safety and success of Livingstone, I am now better supported than ever in my anticipation of his ultimate triumph. Dr. Kirk thus writes:—

"News has reached me, by natives from the interior, that the road is now clear, and that the cholera did not pass the town of Unyanyembe. Livingstone is therefore out of danger, and I hope the stores sent have now reached him. The rainy season being at an end, Unyamwezi caravans are daily expected, and will no doubt bring, if not letters from the Doctor himself, at least news of him from the Arab Governor of Unyanyembe. The coast near Zanzibar is now healthy."

Looking then, as I do, to the astonishing and enduring resolution of my friend, and his thoroughly acclimatized constitution, remembering that he has already gone successfully through privations under which even his attached negro youths all succumbed, I still hold stoutly to the opinion that, by reaching the Albert Nyanza, he will determine the great problem of the watershed of South Africa, and then return to embrace his children, to whom he is devotedly attached, and receive the plaudits, not only of his admiring countrymen, but of all civilized men.

Should this happy finale be brought about, he will have the great additional delight of finding here his venerable father-in-law, the Rev. Robert Moffat, who, after half a century of successful missionary labours, is present at this Meeting of the British Association.

In conclusion, I have the honest satisfaction of knowing that, as President of the Royal Geographical Society, and as the sincere friend of Livingstone, I have, with the warm aid of my deeply lamented friend the Earl of Clarendon, been successful in urging our Government to relieve the great traveller who was gazetted as Her Majesty's Consul to all the kings and chiefs of the interior of Africa.

I have only to add that if diplomatists are recompensed according to the energy and capacity with which they execute their duties, I confidently anticipate that, on his return to Britain, this undaunted Envoy to unknown lands—this sound geographer and zealous Christian missionary—will not only receive a becoming pension, but will also be honoured by some distinction of the Crown, which assuredly our beloved Queen will gladly confer upon him.

Letter from the White Nile. By Sir Samuel Baker, *F.R.G.S.*

In this letter, addressed to Sir Roderick Murchison, Sir Samuel Baker described the proceedings of his expedition up to the 15th June last, and gave an interesting account of the present condition of the White Nile. Previous to his departure from Khartum, he had been assured that the Great White Nile had ceased to be a navigable river. It appeared that the floating rafts of marsh vegetation, which, in 1865, caused an obstruction in the river between the mouths of the Ghazal and Giraffe tributaries, having been neglected by the Khartum authorities, had increased so much as to form now an impenetrable barrier. The vast masses of

floating islands continually brought down the stream had produced a new district many miles in extent, beneath which flows the current of the river. The slave-traders, thus shut out from direct communication with the field of their enterprise, had, however, discovered a passage to the river beyond the barrier, by the Bahr Giraffe, which proved therefore to be an arm of the Nile, instead of an independent stream like the Sobat. In leaving Khartum with his flotilla, Sir Samuel resolved to ascend by this newly discovered passage. He entered the lower mouth of the Giraffe on the 17th February, in N. lat. 9° 26′. The water was 19 feet deep, and the current about $3\frac{1}{2}$ miles an hour, with a breadth, from bank to bank, of about 60 yards. At that time the river was about five feet below the high-water mark of the flood-season. The stream was winding, and had a mean course from the south-west. Four small granitic hills formed good land-marks in the boundless flats within 15 miles of the junction, and fine forests bordered the river for about 30 miles, diversified by plains of extremely fertile soil. As the expedition proceeded the woods ceased altogether, and the steamers depended on the supply of fuel stored in the vessels in tow. At a distance of about 180 miles up the Giraffe the dry land disappeared, and they sailed through a boundless marsh; the river narrowed, the current diminished, and at length progress was stopped altogether by a dense growth of high grass. This was in lat. 7° 47′ 46″, and 272 miles by dead reckoning from the mouth. As the guides assured him that a passage really existed through this to the main Nile, Sir Samuel set 1000 men to work to cut a channel through the obstruction; and, after thirty-two days' labour, a canal, eight miles long, was made, but only to find the stream beyond too shallow to float his steamers. He compared the marsh-grass to sugar-cane in thickness and toughness; and the tangled confusion of decaying vegetation beneath it, to a depth of five or six feet, resembled a mixture of fishing-nets, ropes, mud, sailors' swabs, sponges, and canes, all compressed together in a firm mass, beneath which the water was from ten to twelve feet deep; while grass, about nine feet high, covered the surface as far as the eye could reach from the mast-head. In the clear river, beyond the obstruction, dry land appeared on either bank, and forests within two miles. Herds of antelopes and buffaloes were on the plains, and the rifles secured a supply of meat, which was much needed. From the point where the vessels grounded, Sir Samuel proceeded, with Lieutenant Baker, in a small rowing-boat, hoping to find deep water further ahead; but he found the river impassable, and concluded that the Giraffe was only practicable during the season of flood. The whole flotilla of thirty-four vessels turned back the way they had come; and as the rainy season had set in, putting an end to further progress, he established the encampment, from which he wrote, at Towfikeeya, near the junction of the Giraffe with the Nile. He intended to remain here till November, and then, with all his force of 2000 men, cut a passage through the obstruction in the main river, on his way to Gondokoro. He spoke cheerfully of his prospects; his stores were all safely warehoused, and all his men in fair health. Since his settlement at Towfikeeya he had liberated 305 slaves, who were being carried down the river by slave-dealers; half of them the property of the Turkish Governor of one of the Nile settlements.

On the Great Movements of the Atmosphere. By Alexander Buchan.

The author gave the results of an examination of the mean pressure of the atmosphere and the prevailing winds over the globe, based on barometrical averages calculated for 516 places, and on the mean direction of the wind calculated for 203 places. The broad results were these:—In each hemisphere pressures are highest in winter and lowest in summer. In winter, the highest, and in summer the lowest pressures are over the continents; and in winter very low pressures prevail in the northern parts of the Atlantic and Pacific Oceans. In Central Asia the summer pressure is 0·900 inch less than in winter. This implies the removal in summer of a stratum of atmosphere from the interior of Asia of about 900 feet in thickness. Towards the regions where pressures were high, the winds flow from all directions, not directly towards the centre, but at angles from about 60 to 80 degrees; and from areas of high pressure the winds are found to flow out in every direction.

The prevailing winds over the globe, therefore, at all seasons, obey Buys Ballot's "Law of the Winds" with reference to the distribution of atmospheric pressure. The inflow and outflow of winds are reducible to the single principle of gravitation; and so marked is this, that if there be any other force or forces which put the winds in motion, they must be altogether insignificant as compared with gravitation. The author gave, as the well-digested results of numerous observations, that there was no general flow of the surface-winds of the north temperate zone towards and from the polar regions; the regions of high and low pressure were the true poles of the winds.

On the Physical Geography and Races of British India. By George Campbell, *D.C.L.*

On the Ruined Cities of Central America. By Captain Carmichael.

The author commenced by giving a general descriptive account of these ruined cities, and stated that, in his opinion, formed on personal investigation, the architecture of the Aboriginal Indians of Central America was but a diversified reproduction of that of Eastern countries. He then pointed out a number of similarities in their architecture, designs, customs, &c. to those of the East, and showed how, as a general rule, it was very difficult to explore these ruins, owing to the hostility of the existing tribes of Indians.

As regards their antiquity, he assigned to many of them an earlier foundation than that accorded by Messrs. Stephens and Squier, and adduced some very convincing if novel proofs in support of his theory. The picture he drew of the palace of Quiché, in Guatemala, fully bore out the statement of Torquemada, that they rivalled those of Montezuma; and he showed that if that city, whose foundation has been authoritatively established as coeval with the commencement of a line of sixteen reigns of kings from Nimaquiché, a king of Kichiquel, or, to speak briefly, a city of some eight hundred years' standing, was some fifty years ago in such thorough repair that the Padre of a neighbouring Indian village, who walked among its streets and palaces, imagined himself in Old Spain, what must be the era of those numerous ruined cities compared to which Quiché was modern?

He then pointed out their great length, and added that, in connexion with this, a remarkable fact had seemingly been overlooked by most Central American writers, viz. that the stone buildings whose ruins we now find extant were used as temples, palaces, and public offices generally, the poorer inhabitants living in palm-thatched huts of a perishable nature, an arrangement which represented an almost incredible amount of population.

The author then proceeded to analyze the various elements composing the architecture of the ruined buildings and monuments, and gave an account of the various uses to which the teocali or tumuli were put by the Toltecan and Aztec priests, viz. for sacrificial and burial purposes, to serve as beacons, as warlike defences, &c. He then explained the relations between the temples and alcazars or palaces, and offered a few hints as to the deciphering of the hieroglyphics, a subject to which he has paid much attention, showing that they chiefly were the works of the Indian priesthood, and above all were intended to inculcate moral and religious precepts, chronological events being made entirely subservient, and pointed out their analogy to the stone tablets of Moses, on which were engraven the ten commandments.

The author referred briefly to the round towers which contained the estufas for the sacred fire of Montezuma in connexion with the worship of the sun, and passed on to explain the nature and significance of the various hideous idols to whom human sacrifice was offered on the summit of the teocali, and stated it as his belief that these idols, as well as all the planed stones, were carved with chay or flint instruments. He remarked that he had often found flint and obsidian implements, but in no instance an instrument of metal. He gave a detailed account of a ruined city called Xmul, in British Honduras, which he claims to have discovered; and concluded by expressing his firm conviction in the belief of the existence in

the present day of an Indian city yet to be discovered, whose inhabitants occupy the same splendid palaces and temples as in the days of the Spanish Conquest, and whose priests inscribe fresh precepts on their tablets and altars, and who would then read to us their now mystical hieroglyphics. He supported this statement by giving an account of certain explorations he had made having this object in view. He left these facts in the hands of those interested in scientific discoveries; and should sufficient interest in the matter be awakened from what he had now made known, it would be but another testimony to the valuable results derived from these meetings of the British Association.

On Eastern Tibet. *By* T. T. Cooper.

Holy Islands in the White Sea. *By* W. Hepworth Dixon.

Topographical Sketch of the Zerafshan Valley. *By* A. Fedchenko.

The author was employed during 1869 in a scientific exploration of the valley of the Zerafshan river, in which is situated the city of Samarcand. He penetrated up the valley as far as the Fan river, one of four streams which by their union, according to the natives, form the Zerafshan. The Lake Iskander Kul lies in the mountains, separating the Zerafshan from the Oxus, at an altitude of 7000 to 8000 feet. The river-valley is bordered by mountains of great elevation. Approaching Samarcand the Zerafshan branches off into two channels, reuniting ten or twelve miles lower down (below the city), near Khatyrchi, on the western frontier of the new Russian province of Turkestan. The island thus formed is the richest and most populous district of the entire valley. The country to the north of the river is Steppe; but a considerable portion of it is cultivated, and the road from Tash-Kupriak to Samarcand, a distance of twenty miles, passes almost entirely by gardens and fields. The great volume of water diverted by canals of irrigation from the Zerafshan abundantly satisfies the thirsty ground. The islands formed by the arms of the river have an exceedingly rich soil, and every inch is cultivated with cotton, wheat, barley, rice, millet, or lucerne; the villages are very numerous, and all surrounded by gardens and irrigating canals. The river, rising in lofty, snow-clad mountains, and having a rapid current at certain seasons, fertilizes as well as waters the whole lower district through which it flows, by bringing down a large quantity of earthy sediment. The author gave a description of the various large towns in the valley, and the fairs held in them. In his description of Samarcand, he stated that the city contained 1846 shops, 27 caravanserais, 7 baths, 86 Mesjids, and 23 colleges; the population is 30,000.

Letter on Eastern Turkestan. *By* T. D. Forsyth.

Previous to his departure from Leh, on his present mission to the ruler of Eastern Turkestan, the writer communicated to Sir Roderick Murchison some notes on geographical problems requiring to be solved in this little-known region and the country further to the East. The Yarkand envoy had informed him that the precious stones supposed to come from Khotan were obtained from *Kharkhand*, a place under the sovereignty of the Chief of Kashgar, but situated forty days' march to the east of Khotan. This place is not to be found in the best maps of the Chinese Empire; but it is mentioned by Marco Polo under the name of *Charchan*, which the commentators had supposed to be the same as Karashahar. It appears, however, to be a distinct place, of large size, and situated in a rich country to the north of Lhassa. The road to it, according to the envoy, skirts the foot of a range of mountains, and crosses a large plain, through which run twelve large streams flowing into Lake *Lok*, for so he pronounced Lake *Lob*. The Yarkand and Kashgar rivers, according to the same authority, do not flow into this lake, but lose themselves in the desert. The inhabitants of the shores of Lake Lok live on fish,

and clothe themselves in dresses made of the bark of trees. The present inhabitants of Kharkhand are Mohammedans.

On the Physical Geography of Colorado and adjacent Regions. *By* Governor GILPIN.

On Lines for a Ship-Canal across the American Isthmus. *By* General W. HEINE, *U.S.A.*

The author visited the Atlantic side of the isthmus early in the present year on a mission intended to examine the correctness of the statements of M. Lacharme, an engineer who explored the interval from the Tuyra River on the Pacific side and the Cacarica branch of the Atrato on the Atlantic, and declared there were no great obstacles to the construction of a canal at that point, the length to be cut being only 52 miles, and the greatest elevation only 186 feet. The author was not able to ascend the Atrato, but all he saw went to confirm M. Lacharme's statements. These he gave in detail, showing that they were founded on a conscientious survey, with all necessary scientific instruments. From his own observations and those of the recent United States Survey, the author demonstrated the utter impracticability of any other part of the isthmus for the purposes of an interoceanic canal, and insisted upon the necessity of a further survey by the line of the Atrato and Cacarica.

On the Great Currents of the Atmosphere. *By* JOHN K. LAUGHTON, *M.A.*, *F.R.A.S.*, *F.R.G.S.*

The author pointed out several geographical facts which were opposed to the received theory of the trade-winds, known as Hadley's theory. Heat does not cause a wind towards any of the principal areas of greatest temperature; either towards the Desert of Sahara, the Arabian Desert, the interior of Australia, the Red Sea, the Persian Gulf, or even, when carefully traced, towards the Great Prairie of North America. The effect attributed to the rotation of the earth also is not consistent with numerous observed facts, such as the S.E. wind in the Gulf of Mexico, the N.W. wind on the coast of North Africa, between Cape Verde and Cape Palmas, the N.W. gales in the North Atlantic, the S.W. wind on the south coast of Australia, and very many others; the idea, indeed, appeared to have been formed in a temporary forgetfulness of the power of friction, which in the case of air is very intense. Winds which, in accordance with Hadley's theory, have been very generally divided into polar and equatorial, seem more naturally to divide themselves into easterly and westerly. As our experience grows larger, we learn that the westerly winds have an extent and a power incompatible with the idea of their secondary nature. They extend from 60° N. to 60° S., interrupted only by the trade-winds. The trade-winds are small in comparison, and of very limited height, the westerly winds blowing above them as strongly as they do both above and near the surface in temperate zones. The westerly are really the primary winds, whilst the equable trade-winds, of very limited volume, are reflex streams of air caused by the impact of the great westerly winds on the continental barriers, whether against mountain-ranges or against the more sluggish air which lies over the land. In the Atlantic we see the main westerly stream of air dividing, on about the parallel of 45° N., and turning north as a S.W. wind on our coasts, or south as a N.W. and N. wind on the coast of Portugal. On the other hand, at the extreme west, the westerly wind continually dragging away the air from the eastern side of the Rocky Mountains, causes such a tendency towards a vacuum, that the air from the south and north is induced towards it. It was impossible to say definitely why the atmosphere should have this prevailing westerly motion, but the author was inclined to seek its cause in the attraction of the heavenly bodies.

The Landfall of Columbus. *By* R. H. Major, *F.S.A., Hon. Sec. R.G.S.*

It is surprising that after the lapse of nearly four centuries there should be any doubt as to the spot in the New World which was first lighted on by Christopher Columbus. In this paper the author set himself to show, not only that the name which Columbus gave to that spot was for nearly two centuries applied to an island to which it never belonged, but that among the advocates of various islands for the honour of being the true landfall the very latest had to be confuted, while the one who had adduced the best arguments in favour of the correct island had been greatly at fault with respect to the point of anchorage. Columbus gave the name of San Salvador to the island which he first discovered. Its Indian name was Guanahani. In 1793 Juan Bautista Muñoz, in his 'Historia del Nuevo Mundo,' declared his belief that Guanahani was Watling's Island, in contravention of the maps which from the beginning of the eighteenth century had given the name of San Salvador to Cat Island. In 1825 Navarrete, in his 'Coleccion de los Viages y descubrimientos que hicieron por mar los Españoles desde fin del siglo xv.," believed it to be Turk's Island. In 1828 Washington Irving, in his 'Life of Columbus,' decided in favour of Cat Island, relying mainly on Captain Slidell Mackenzie's interpretation of the 'Diary of Columbus;' and in 1837 this conclusion received the weighty approval of the Baron Alexander von Humboldt in his 'Examen Critique de l'Histoire de la Géographie du nouveau Continent.' In 1856 the claims of Watling's Island found a fresh champion in Capt. Becher, of the Hydrographic Office, in his work entitled the 'Landfall of Columbus;' but in 1864, and again so late as 1869, Senhor de Varnhagen, in his 'Verdadera Guanahani de Colon,' has put in a claim for the island of Mayaguana. The author of the paper first examined these respective claims by the light of the 'Diary of Columbus' himself, the real fountain-head of information upon the subject; and having shown therefrom that the arguments in favour of Cat Island, Turk's Island, and Mayaguana were untenable, proceeded to fix the identity of Guanahani with Watling's Island by a process which reduced the chances of error to a minimum. He produced a facsimile diagram of a map of the Bahamas published in 1601 by Herrera, the official historiographer of the Indies in Spain, and laid down by him from the original documents in the handwriting of Columbus and his contemporaries, which, in his official position, he had under his special charge. The value of this authoritative map was all the greater that it was constructed before any question was raised on the point in dispute; it was new enough to contain all the islands in their approximately correct position, but old enough to contain, not only the name of Guanahani, but a large proportion of ancient names identical with those at present existing. Side by side with this was a diagram made from the Admiralty Survey, showing these islands as now known, and with their modern names. Out of twenty-four islands thus brought under comparison, ten retained, in the modern map, the same names as they held in the old, thus affording valuable stations for accurate comparison. Of these ten, one was Senhor de Varnhagen's Mayaguana itself, which was represented, *together with* the island of Guanahani, on Herrera's map; so that His Excellency's claim was completely neutralized, since by no possibility could two islands be made identical which were so markedly distinct as to have several other islands lying between them. The comparison between the two diagrams plainly showed that Guanahani was Watling's Island. But while thus demonstrating the correctness of the conclusions of Muñoz and Capt. Becher on this head, the author entirely disagreed with the latter as to the point where the Admiral first anchored off that island, and also as to his movements while there. Capt. Becher makes Columbus anchor a little to the south of the N.E. point of the island; and when he tripped his anchor, makes him sail round the northern end of the island. He also makes Columbus's ship follow the boats in their reconnaissance. Not one of these statements or conclusions is in accordance with the 'Diary,' nor would such a movement lead to the topographical discoveries recorded. The 'Diary' says that Columbus took the ship's boat and the caravel's barges and went along the island in a N.N.E. direction to see the other part of the island to the eastward; and as the trending of the southern part of the east side of the island is itself N.N.E., it is clear that such a movement necessitates starting from a point on the S.E. of the

island. This very manifest fact is in accordance with the discoveries made by Columbus on the island, and also with what took place when Columbus left his moorings for the second island, for he then saw several islands, and was doubtful which he should visit first. This would really be the case when starting from the S.E. point of Watling's Island, but would not hold good if he started from the anchorage assigned by Capt. Becher; so that the author has here, for the first time, demonstrated that the first anchorage of Columbus in the New World was off the south-east point of Watling's Island.

On Railway Routes across North America and the Physical Aspects of the Country. By Lord Milton, *M.P., F.R.G.S.*

Journey into the Interior of Hadramaut. By Werner Munzinger.

The author, after recovering from wounds received in Abyssinia, accompanied Capt. Miles on an excursion eastward from Aden towards the interior of Arabia. The region traversed abounded in Himyaritic inscriptions and in other vestiges of remote civilization. The travellers went by sea as far as Bir Ali, and travelled thence into the interior for a distance of about 300 miles, their furthest point being a place called Habban, 3000 feet above the level of the sea. Their route was laid down by compass bearings, and they took barometric observations for height. From Bir Ali the country formed a plain with a gentle slope inland, nearly covered by isolated hills and ridges of sandstone with flat tops, all of the same height, about 1500 feet above the plain, and quite destitute of vegetation: the very narrow strips of alluvial soil in the ravines, not one-tenth of the whole, are alone capable of cultivation; but these are generally well cared for, and yield three and even four crops in the year, being irrigated by wells. These patches form a number of oases with a dense population and towns of several thousand inhabitants. The people cultivate dates, millet, wheat, and the Abyssinian grain called *tef*. Water is generally met with, in boring, about fifty feet from the surface. Beyond this region, and further inland, they came to what M. Munzinger called a granitic and metamorphic land, with rounded hills bounding several wide plains. Here there was more vegetation, with some fine trees; and wild hogs, gazelles and herds of cattle were met with. The people belonged to different races, and the Himyaritic language was not entirely lost or forgotten, in spite of 1200 years of Islam. But all spoke Arabic, though in a very strange dialect; there was an absence of religious feeling and of regular government, and civilization was at a very low ebb, the only sign of it being the very large houses with several stories, each of them a castle in itself. The travellers met with little hospitality, but were not actually ill-treated. At Ghorab they were near the Desert of Akhaf, described by Wrede, and the Bahr el Saffi, or Sea of Saffi, so called from King Saffi, who, in an attempt to cross the desert, disappeared with his entire army. The desert was described as an immense sandy plain, covered with numberless undulating hills, which gave it the appearance of a moving sea, and as lying 1000 feet below the level of the granitic land. On the desert are white patches formed of impalpable powder, into which if a plummet with a sixty-fathom line is thrown, the whole slowly disappears. In one of these quicksands the ill-omened King Saffi and his host found a tomb. The whole region of Hadramaut and Yemen is full of curious legends, and abounds in geographical and historical questions of the deepest interest. The author confessed that the excursion of Capt. Miles and himself formed but a small contribution to our knowledge of Arabian geography, but hoped it would incite other travellers to explore this nearly unknown land.

Notes on the Site of the Terrestrial Paradise. By Major-Gen. Sir Henry Rawlinson, *K.C.B., LL.D., D.C.L., F.R.S.**

In this paper the author propounded, as the result of his investigations of Semitic antiquities and of the Cuneiform Tablets of Babylonia, a new hypothesis

* This paper will be printed *in extenso* in the Journal of the Royal Geographical Society.

regarding the site of the traditional Garden of Eden of the Hebrews. He remarked, in the first place, that on examining the early traditions of nations, we invariably found the Heaven-land, the abode of the gods, the connecting-link between divinity and humanity, to lie in that region of the earth from which the recording race took its intellectual origin. In illustration of this he need only refer to the Olympus of the Greeks and the Merú of the Aryans, which latter had three sites, according to the habitat of the three branches of the Aryan race; the Persians, or Western Aryans, placing their Irán-víj in the Paropamisus, while the Merú of the Central Aryans was in Pamír, and of the Eastern about the Sacred Lakes in Thibet, and in each of these there were supposed to be four rivers flowing from a common centre. There was ground, then, for supposing the Paradise of the Hebrews to lie in that region which was the cradle of the nation, namely, near Ur of the Chaldees, which the author had been able to demonstrate, from cuneiform inscriptions, to have been situated on the lower Euphrates, at the place now called Muzheir. The name of "Hebrew" was also derived from the same locality, the zone, or belt, of alluvial land between the river and the tertiary formation having the specific title among the Arabian geographers of *Ibr*, or "the bank;" so that *Ibri* was a perfectly correct ethnic title for the Abrahamic emigrants. Further, the author suggested that *Gan-eden*, which we translate "Garden of Eden," was nothing more than the Hebrew rendering of one of the old vernacular names of Babylonia, which was *Gana-duni* (or, with the case-ending, *Gana-duniyas*), *Gana* signifying apparently "an enclosure," while *Duni* or *Aduni* was one of the earliest gods worshipped in the country. Without, however, insisting on this identification of the name of the country, he would rely mainly on the names and attributes of the four rivers which watered the garden, and which were evidently intended, as Kalish has remarked, to furnish an exact geographical description of Eden. These rivers, as it is well known, were Pison, Gihon, Hiddekel, and Euphrates. Now the land of Babylonia was constantly illustrated in the cuneiform inscriptions by the names of four rivers, two of which answer to the Tigris and the Euphrates, and the other two were named the *Surrapi* and the *Ukni*. The latter two were Assyrian terms, and their Babylonian equivalents had not yet been identified. The *Surrapi* seemed, however, to answer partly to the Biblical Gihon, and *Ukni* to the Pison, and they represented respectively the left hand, or eastern arm of the Tigris, and the right hand, or western arm of the Euphrates.

Regarding the Pison, it is said in Genesis, "The name of the first is Pison, that is it which compasseth the whole land of Havilah, where there is gold; and the gold of that land is good: there is bdellium and the onyx stone." The name *Pisun*, coming from the Hebrew verb "to disperse," signifies "the overflow;" and as in all ages there has been an outlet to the Euphrates above Babylon, where the flood drains off to the south-east, varying constantly in its course and name, and as *Ukni* had been shown on independent grounds to mean "the onyx," or "the onyx-river" (though probably the term really refers to alabaster, quarries of which existed just outside the Euphrates alluvium), the author considered there was good reason for identifying the stream with the Pison of Genesis. Bdellium he considered to mean "pearls" (*Bedolat*), which were obtained at the mouth of the river, from the banks in the Persian Gulf; and the land of Havilah he believed to be the strip of sandy desert which skirts the Arabian upland; *Haul* signifying simply "sand."

With regard to the Gihun, or the river "which compasseth the whole land of Cush," his theory was, that in very early times the left branch of the Euphrates, which left the main river just above Babylon and ran due east to the Tigris, was considered to be the same as the left arm of the Tigris itself, that arm being prolonged in the same line to the eastward, while the right arm of the Tigris was considered to be the true continuation of the upper course of the river following the same general direction of south-east. In a rough way, it might be said that the left arm of the Euphrates thus crossed the Tigris and formed the Gihun. He justified this theory on philological grounds, showing that the left arm of the Tigris had retained the name of *Guhá*, absolutely identical with the Hebrew reading of Gihon, almost to the present day, and discussed the whole subject in some detail. As to the description of the Gihun as "encompassing the whole land of Cush" (which, by a very bold guess, our translators had rendered "Ethiopia"), "*Cush*," or

"*Kish*," was one of the primitive capitals of Babylonia, and it gave its name apparently to the whole country along the river. "*Kusiya*" was mentioned in that quarter among the possessions of Darius Hystaspes. Various other reasons for this identification were adduced.

The third river offered fewer difficulties, as no one had ever doubted that the Heddekel was the Tigris. The fourth river was *Perat*, or the Euphrates. In the inscriptions the word is often represented by the sign for "water," in the same way as it is called in Scripture "the great river;" but usually the upper river has the name of *Purat*, where we have probably a very ancient root, signifying "to abound" or "fructify," common to both the Aryan and Semitic tongues; the lower river, below the Pison branch, is called in the inscriptions the river of Sippara, from the town of that name.

Early Traditions regarding the River Oxus.

By Major-Gen. Sir H. Rawlinson, *K.C.B., LL.D., D.C.L., F.R.S., &c.*

Whether Bournouf was right or not in regarding the term *Pámir* (the region in which the Oxus takes its rise) as a contraction of *Upá Méru*, "the country above Mount Meru," and in thus associating the name directly with the holiest spot in the Brahmanical Cosmogony, the author of the paper thought it was certain that the geographical indications of the Puránas all pointed to this quarter of Central Asia as the site of the primæval Aryan Paradise. We were not, however, limited to Sanscrit authorities in studying this subject; the Puránas were supplemented by the traditions and travels of the Buddhists, and in these later sources of information we often find evidence of so direct a nature as almost to meet the requirements of modern science. Thus, in regard to the four rivers of the Aryan Paradise, which were named by the Brahmans, 1, the Sita; 2, the Alakananda; 3, the Vakhshu; and 4, the Bhadra, the Buddhists varied both the order and the nomenclature, classing the four rivers as, 1, the Ganges; 2, the Indus; 3, the Oxus; and 4, the Sita; and, further, deriving them from a great central lake, which was named A-neou-ta, and one of the representatives of which was either the Kara-kul or the Sarik-kul Lake of Pamir. The Buddhist traveller Hiouen-thsang in A.D. 644 recognized in the Tsung-ling, or Pamir chain, the Sú-merú of his national cosmography. Capt. Wood, in the account of his journey to the sources of the Oxus, had furnished us with an explanation of the origin of the old legend of a four-rivered Paradise. He observes that "the hills and mountains which encircle Sir-i-kul, give rise to some of the principal rivers in Asia. From the ridge at its eastern end flows a branch of the Yarkand river, one of the largest streams that waters Chinese Tartary, while from the low hills on the northern side rises the Sirr, or River of Kokan, and from the snowy chain opposite, both forks of the Oxus as well as a branch of the River Kuner are supplied." Although the position of these various streams is now known to be incorrect, we had a right to infer that the many-rivered wealth of Pamir had so impressed the imagination of the primitive Aryan colonists that in their subsequent migrations towards the south, and with a more extended geographical knowledge, they transferred the physical features of the fatherland to the abode of Brahma and the gods, precisely in the same way as the Semitic Jews, after being transplanted to the coast of Syria, preserved in their delineation of the terrestrial Paradise the memory traditionally handed down of their old habitat in Babylonia between the Tigris and the Euphrates. Another Aryan legend confirmed this presumed connexion between the head-streams of the Oxus and the several rivers of Asia which were fabled to fall from heaven upon Mount Meru, thence to flow to the surrounding world. One version of the Puranic legend described the rivers flowing from Mount Meru as seven; and this had its parallel in the popular geography of Pamir, for the region of the Upper Oxus was known to the Iranian division of the Aryan race by the name of the Country of the Seven Rivers. The passage in the Vendidad to this effect was confirmed by Abu Rihan El-Biruni, a very competent authority. The author believed that a critical examination of the geography of the Puránas might lead to some curious results as to the period and track of the various Aryan migrations.

Journey to the Upper Waters of the Niger. *By* W. Winwood Reade.

In the course of his recent journey of exploration in the interior of Western Africa, undertaken under the auspices of the Royal Geographical Society, and at the cost of Mr. A. Swanzy, the author penetrated to Farabana, on the Upper Niger, and to Bouré, celebrated for its gold-fields, 450 miles from Sierra Leone. He returned from Sierra Leone to Falaba, on his second attempt to reach the Niger, at the end of June, 1869, and within a month of starting had the pleasure of beholding the great river, at the large and previously unknown town of Farabana. The Niger here was only 100 yards broad, and canoes for the passage of travellers were only used during the rainy season. The Upper or Western Niger had been previously visited by travellers at two points,—by Mungo Park at Segon and by Caillié considerably higher up; but the point reached by the author was the highest yet attained, and he claimed to have discovered the shortest and best route yet known from Sierra Leone to the river—a discovery which would eventually lead to important commercial results, and which established the singular fact of the rise of the river within so short a distance of the sea into which it flows.

On the Basin of Lake Titicaca. *By* E. G. Squier.

The author gave the result of his recent explorations, in company with Prof. A. Raimondy, in the district of Lake Titicaca, in South Peru. The elevated plain in which this lake, as well as that of Aullagas, is situated, forms a terrestrial basin, termed by the author the Thibet of America. It has an estimated length of between 500 and 600 miles, its width varying from 100 to 200 miles, the total area being calculated at about 100,000 square miles. Its eastern border is bounded by the loftiest part of the Andes, a vast unbroken, snow-crowned range, whose lowest peaks rival Chimborazo in altitude. The slope of the Titicaca basin is gentle towards the south, and the waters of the lake lie at the great elevation of 12,864 feet above the level of the sea. Some of its tributaries are scarcely fordable even in the dry season; and its waters are discharged through a broad, deep and swift, but not turbulent stream, El Desaguadero, into Lake Aullagas; it is therefore a freshwater lake. The Desaguadero is about 170 miles long, and has a fall of not far from 500 feet. Of Lake Aullagas, which the author did not visit, almost nothing is known. The maximum length of Titicaca is nearly 120 miles, and its greatest width between 40 and 50 miles. The lake had been explored by Mr. Pentland in 1827–28 and in 1837; and his chart, published by the Admiralty, was still the most trustworthy guide to its geographical features. Messrs. Squier and Raimondy navigated it for three weeks in an open boat, and the author of the paper bore testimony to the general accuracy of Mr. Pentland's observations. There were, however, some errors, and these he had rectified in a map he (Mr. Squier) had published. The eastern, or Bolivian shore of the lake is abrupt, but the western and southern shores are relatively low; and the water in the bays and estuaries is grown up with reeds and rushes, amid which myriads of water-fowl find shelter and support. The roads across the marshes are stone causeways of Inca origin. It was easy to see that the lake once covered a much larger area than it now occupies. In many places, a line of 100 fathoms did not reach the bottom. The difference of level between the dry and wet seasons amounted to from 3 to 5 feet. The dry season leaves bare a large tract of land, covered with a kind of tender lake weed, called in the Quichua language *llacta*, and this supports herds of cattle at a time when the pasturage of the drier country is withered. The lake never freezes over, but ice forms near its shores and where the water is shallow. Its waters during the winter months are from 10° to 15° Fahr. warmer than the atmosphere, and therefore exert a favourable influence over the climate of its shores and islands. The prevailing winds are from the north-east, whence they often blow with great force; and severe storms are not infrequent. The efforts to place steamers on the lake have failed, chiefly owing to the scarcity of fuel. The population of the neighbourhood consists chiefly of Aymara Indians, between whom and the Quichuas there is physically a marked difference.

On the South-African Gold-fields. *By* Captain Sir John Swinburne, *Bart.*

The part of South Africa treated of by the author was the district lying between the Limpopo and the Zambesi rivers, and between 27° E. long. and the Indian Ocean. The shortest practicable route to it is by way of Port Natal and Harrismith. There is no public conveyance between Maritzburg and Harrismith, a distance of 150 miles, and the road is very bad, as all the rivers and valleys are crossed at right angles. The Drakensberg is crossed on the road at an altitude of 5400 feet. From Harrismith to Potchefstroom, a distance of 190 miles, the country is undulating and almost destitute of wood. Seventy-five miles further Rustenburg is reached, the last civilized place in the interior; hence to the Tati river is a march of 382 miles through the bush country, a monotonous, arid tract, wooded with stunted trees rarely exceeding sixty feet in height. The mining settlement on the Tati is situated in lat. 21° 27′ S. and 27° 40′ E. long., at an elevation of 3200 feet above the sea. The Southern Gold-fields, as far as the actual metal has been found, extends from N.W. to S.E., a distance of forty miles by fourteen miles broad. There are five different mines within a mile of the settlement; two three miles to the south-east, one thirteen miles north; two twelve miles, and one thirty-five miles up the river, to the north-west of the settlement; making a total of eleven mines which have actually been worked and gold extracted. Besides these there are numerous other reefs where gold has been discovered; but these have not yet been worked. In most of the mines two shafts have been sunk to an average depth of fifty feet, and all are upon the site of ancient workings. The original miners appear to have worked the reefs more in the manner of quarries than mines, leaving great holes or pits. There are two descriptions of quartz,—one red and honeycombed, the other of a bluish-grey appearance, the gold in the latter being coarser, but more easily discriminated than in the red ore. The climate of the gold country is very healthy. From the end of April to October no rain falls; the other months are subject to violent thunder-storms, but there is scarcely a day without some hours of fine weather: the nights are always cold, in June the thermometer falling as low as 38° Fahr. about an hour before sunrise, while it ranges as high as 88° or 90° during the day. The prevailing wind for nine months of the year is S.E., blowing strong during the day, and dying away at sunset. The Northern Gold-fields lie 327 miles to the N.N.E. of the Tati, in the Zambesi basin, their northern part being the Umfuli river (the Tole or Banyeka of Livingstone's map), and their southern boundary the Bembees. The latitude of the principal workings is 18° 11′ S., and the longitude 30° 34′ E., and they are distant 205 miles from Tete, and 160 miles due south of Zumbo, on the Zambesi; at present they have not been very productive. The country is densely peopled by the Meshuna nation, industrious workers in iron and earthenware, and growing all kinds of grain and pulse. The author, who visited these previously almost unknown people, gave a sketch of their recent dealings with the invading Matabele Caffres.

The Island of Hainan. *By* R. Swinhoe, *F.R.G.S.*

Mr. Swinhoe visited the island of Hainan on Government service in 1868, to inquire into its commercial capabilities. He describes the island of Navchow, near Hainan, which was first visited. The chief port (Hoihow) and the capital of Hainan (Kiungchow) are then described, and an account is given of a visit to the mountains of the interior, and an interview with the independent aborigines called Le. Leaving the chief port, the gunboat 'Algerine,' Commander Domvile, which carried the expedition, circumnavigated the island, calling at the most important harbours and places on the coast. Some account is given of each of these.

On the Harbours of Western India. *By* Capt. Taylor, (*late*) *I.N.*

During his service in the late Indian navy of nineteen years' duration, the author has been employed in surveying various harbours hitherto unused on the western coast of India; and as the results of these surveys, showing the existence of harbours of great capacity and excellence, had been published, he was naturally sur-

prised to learn last spring that "the Viceroy has applied to the Home Government to send out a civil engineer, possessed of special experience, to be employed in examining the coast of India, with the view of discovering sites for ports." Among the ports surveyed by the late Indian Navy were, first, Poshetra and Seraia, or Kambalia, situated at the entrance of the Gulf of Kutch, and sheltered from all the prevailing winds. Either of them is capable of receiving the largest iron-clad of the navy. Seraia might be compared to the Mersey, and Poshetra was something between Cork Harbour and Milford Haven, without their hilly features. No expensive breakwaters were needed, and they simply required lights and beacons to guide vessels in and out, wharves for ships to lie alongside, and roads in the interior to bring down produce. Since the opening of the Suez Canal, the northern position of these ports, which previously would have been a disadvantage, has become one of their strongest recommendations. They are 300 miles to windward of Bombay, *i. e.* nearer to Aden, in the south-west monsoon, the season when the fresh crops require carriage to Europe. Neither steamer nor large sailing-vessel would find real difficulty in getting out of the Gulf of Kutch. The author found that the strong winds of the south-west monsoon blew only for three or four days at a time, and then abate for a day or two. The Muálims, or pilots of Kutch, are a caste deservedly famous for skill and daring; many of them have quadrants and nautical tables, and can determine the latitude by sun and pole-star, and their longitude by dead reckoning. Some of their boats are large, well built, and decked, and carry a pair or two of carronades. Large native vessels coming from the Malabar and African coasts can now, after the commencement of the south-west monsoon, boldly run into the gulf. A third important harbour on the coast of Katiawar was Chanch Bunder, formed by Shalbet Island, and surveyed by the late Capt. R. Ethersay. Southward of Bombay there was the excellent harbour of the Rajpuri, or Jinjera river, without the usual bar of sand that is found at most river-mouths along this coast, but having $3\frac{1}{2}$ and $3\frac{3}{4}$ fathoms at low tide, and $4\frac{1}{2}$ fathoms inside in mid-channel. Next to this, following a southerly direction, was the Jyghur, or Shastri river, the principal channel to which has 3 fathoms at low tide. Kalbadevi Bay, Viziadroog, Desghur, Sedashighur Tudri, or Mirjan river, and various other ports capable of being made serviceable in our commerce with India, were also described in some detail.

On Windward Great Circle Sailing. *By* JOHN T. TOWSON, *F.R.G.S.*

The author referred to the tables constructed by him, and published by the Admiralty twenty-four years since, in which he pointed out the value of windward great circle sailing. The other modification of this sailing had been brought into successful use; but windward sailing, although it appeared most simple, had been generally misunderstood by practical men. Some had obtained charts having great circle routes laid down. If they were driven from this track by adverse winds, they returned as soon as the wind would permit them, not perceiving that when they had quitted one great circle there was another great circle, which was their nearest route. Others imagined that this sailing consisted in going a certain number of miles to the northward. The rule was simple:—"Find the great circle course, and put the ship on that tack which is the nearest to the great circle course." In January last he was invited by Mr. Ashbury to prepare sailing-directions for the 'Cambria' yacht. The directions which he prepared were shown by a chart. It consisted of the great circle course, corrected for variation for every part of the Atlantic that it was probable that a vessel should pass. All the mariner had to do was to ascertain his approximate position, and then he would find by inspection how to keep the ship's head by compass. The distance from the place of destination was also given by another chart, containing the position of both yachts at noon for each day. Mr. Towson showed that the 'Cambria' saved the race by superior navigation. This sailing gave the greatest advantage when the distance of longitude was greatest; and thus the 'Cambria' attained all the advantage that this sailing could afford in the first five days, which was about 110 miles; afterwards the superior power for an ocean race possessed by the 'Dauntless' prevailed, and reduced this advantage to a minimum.

The principal objection that of late has been raised against great circle sailing is "the series of ever-changing courses which a vessel must pursue." This is correct with regard to true courses; but it will be seen, by reference to the large chart, that compass courses across the North Atlantic vary less than those on a rhumb or on a parallel.

Notes on Analogies of Manners between the Indo-Chinese and the Races of the Malay Archipelago. By Col. H. Yule, *C.B.*

The author believed the Malayan race to be closely connected with the Indo-Chinese, although their language, which is not one of monosyllables, marked a great present distinction. He had seen faces of natives from Java, on the one hand, and of natives of Burmah and of the mountains on the eastern frontiers of Bengal on the other, as near identity as human faces ever are; whilst there are many particulars common to the customs and peculiarities of the two regions which seem to argue a close relationship. One of these common traits is the aversion to the use of milk; in Bali, where alone among the islands the Vedas still exist, a preparation from the cocoa-nut is substituted for *ghee* in the Hindoo rites. Another is the wilful staining of the teeth; and the singular custom of covering the teeth entirely with a case of gold, noticed by Marco Polo among a people of Western Yunnan, existed, at least recently, in Sumatra, Timor, and at Macaisar. The extravagant enlargement of the ear-lobe is also common to most of the tribes of both regions. Another coincidence is an idiom of language of remote origin, in which a term is added to a numeral in the enumeration of objects, analogous to our word "head" in expressing a number of cattle, and of which there are a large number of cases in the Malay language. Precisely the same peculiarity is found in the Burmese, Siamese, and Chinese tongues; and the propensity may be referred to a dislike to abstract numbers. The savage mania of hunting for heads, generally by nocturnal ambuscade, and of treasuring them as trophies, is found, with almost identical circumstances, among the wild Dayaks and Kayans of Borneo and Celebes, and the wild Kukis, Nagas, and Garos of the eastern frontier of Bengal. A superstitious abstinence from certain articles of diet, which is hereditary and binding among certain families only, is found here and there with remarkably coincident circumstances among the tribes of both regions. Another very notable custom is the association of the whole of the families of one village or community in one or in several great houses or barracks. This appears to be general among some of the Dayak tribes of Borneo and among the rude natives of the Pági islands, off the west coast of Sumatra. The very same practice is found among the Singphos, north of Burmah, and among the Mekirs and Mishmis of the Assam border. The practice of ordeal by water is found, with singular exactness of agreement in the circumstances, at intervals over both the regions compared. No one can doubt the common origin of the music and musical instruments of Burmah and Java, vastly superior as they are in spirit and in melody to any thing called music in India proper; there is also an extraordinary similarity of dramatic entertainments in Burmah, Siam, and Java.

The author concluded by stating that these and many other coincidences which he detailed were singly of no value as arguments for some original close bond of kindred, as isolated coincidences occur between the practices of the most distant tribes of the earth, but that their great number must be admitted to have great weight, especially considering the contiguity of the two regions.

ECONOMIC SCIENCE AND STATISTICS.

Address by Professor W. Stanley Jevons, *M.A., President of the Section.*

The field of knowledge which we cultivate in this Section is so wide, that it would be impossible, in any introductory remarks, to notice more than a few of the important questions which claim our attention at the present time.

The name Statistics, in its true meaning, denotes all knowledge relating to the condition of the State or people. I am sorry to observe, indeed, that many persons now use the word *statistical* as if it were synonymous with *numerical*; but it is a mere accident of the information with which we deal, that it is often expressed in a numerical or tabular form. As other sciences progress, they become more a matter of quantity and number, and so does our science; but we must not suppose that the occurrence of numerical statements is the mark of statistical information.

In order, however, that any subject can be fitly discussed by a Section of this Association, it should be capable of scientific treatment. We must not only have facts, numerical or otherwise, but those facts must be analyzed, arranged, and explained by inductive or deductive processes, as nearly as possible identical with those which have led to undoubted success in other branches of science. I have always felt great gratification that the founders of this Association did not in any narrow spirit restrict its inquiries and discussions to the domain of physical science. The existence of this Section is a standing recognition of the truth that the condition of the people is governed by definite laws, however complicated and difficult of discovery they may be. It is no valid reproach against us that we cannot measure, and explain, and predict with the accuracy of a chemist or an astronomer. Difficult as may be the problems presented to the experimentalist in his investigation of material nature, they are easy compared with the problems of human nature, of which we must attempt the solution. I allow that our knowledge of the causes in action is seldom sure and accurate, so as to present the appearance of true science.

There is no one who occupies a less enviable position than the political economist. Cultivating the frontier regions between certain knowledge and conjecture, his efforts and advice are scorned and rejected on all hands. If he arrives at a sure law of human nature, and points out the evils which arise from its neglect, he is fallen upon by the large classes of people who think their own common sense sufficient; he is charged with being too abstract in his speculations, with overlooking the windings of the human heart, and with undervaluing the affections. However humane his motives, he is lucky if he escape being set down on all sides as a heartless misanthrope. Such was actually the fate of one of the most humane and excellent of men, the late Mr. Malthus. On the other hand, it is only the enlightened and wide-minded scientific men who treat the political economist with any cordiality. I much fear that, as physical philosophers become more and more successful, they tend to become, like other conquerors, arrogant and selfish; they forget the absurd theories, the incredible errors, the long enduring debates out of which their own knowledge has emerged, and look with scorn upon our economic science, our statistics, or our still more vague body of knowledge called social science, because we are still struggling to overcome difficulties far greater than ever they encountered. But, again, I regard the existence of this Section as a satisfactory recognition of the absolute necessity of doing our best to cultivate economic subjects in a scientific spirit.

The great and everlasting benefits which physical science has conferred upon the human race are on every side acknowledged; yet they are only the smaller half of what is wanted. It daily becomes more apparent that the highest successes in the scientific arts and manufactures are compatible with deep and almost hopeless poverty in the mass of the people. We subdue material nature, we spin and weave, and melt and forge with a minimum of labour and a maximum of result; but of what advantage is all this while human nature remains unsubdued, and a large part of the population are too ignorant, careless, improvident, or vicious to appreciate or accumulate the wealth which science brings. Chemistry cannot analyze the heart; it cannot show us how to temper the passions or mould the habits. The social sciences are the necessary complement to the physical sciences, for by their aid alone can the main body of the population be rendered honest, temperate, provident, and intelligent.

In this kingdom during the last thirty or forty years we have tried a mighty experiment, and to a great extent we have failed. The growth of the arts and manufactures and the establishment of free trade have opened the widest means of employment and brought an accession of wealth previously unknown; the fre-

quent remission of taxes has left the working classes in fuller enjoyment of their wages; the poor laws have been reformed and administered with care, and the emigration of millions might well have been expected to leave room for those that remain. Nevertheless within the last few years we have seen pauperism almost as prevalent as ever, and the slightest relapse of trade throws whole towns and classes of people into a state of destitution little short of famine. Such a melancholy fact is not to be charged to the political economist; it is rather a verification of his unheeded warnings; it is precisely what Malthus would have predicted of a population which, while supplied with easily earned wealth, is deprived of education and bribed by the mistaken benevolence of the richer classes into a neglect of the future. What can we expect while many still believe the proverb that "Where God sends mouths, He sends food," and while a great many more still act upon it?

I am glad to say that, ic spite of all opponents, we have an education act. Three centuries ago the State re ognized the principle that no person should be allowed to perish for want of bread; for three centuries the State has allowed the people to perish for want of mind and knowledge. Let us hope much from this tardy recognition of the greatest social need, but let us not withdraw our attention from many other causes of evil which still exist in full force. I wish especially to point out that the wise precautions of the present poor law are to a great extent counteracted by the mistaken humanity of charitable people. Could we sum up the amount of aid which is, in one way or other, extended by the upper to the lower classes, it would be almost of incredible amount, and would probably far exceed the cost of poor-law relief. But I am sorry to believe that, however great the good thus done, the evil results are probably greater. Nothing so surely as indiscriminate charity tends to create and perpetuate a class living in hopeless poverty. It is well known that those towns where charitable institutions and charitable people most abound are precisely those where the helpless poor are most numerous. It is even shown by Sir Charles Trevelyan, in a recent pamphlet, that the casual paupers have their London season and their country season, following the movements of those on whom they feed. Mr. Goschen and the poor-law authorities have of late begun to perceive that all their care in the administration of relief is frustrated by the over-abundant charity of private persons or religious societies. The same family often joins parish relief to the contributions of one or more lady visitors and missionaries. Not only improvidence but gross fraud is thus promoted, and cases are known to occur where visitors of the poor are duped into assisting those who are secretly in possession of sufficient means of livelihood.

Far worse, however, than private charity are the innumerable small charities established by the bequests of mistaken testators. Almost every parish church has its tables of benefactions, holding up to everlasting gratitude those who have left a small patch of land or an annual sum of money to be devoted to pauperizing the population of the parish throughout all time. Blankets, coals, loaves, or money are doled out once or twice a year, usually by the vicar and churchwardens. More or less these parish charities act as a decoy to keep the most helpless part of the population nominally within the fold of the Church. The Dissenters, where they are strong enough, retaliate by competing for the possession of the poor by their own missions, and thus the reproach of the Roman Catholic Church, that it fostered mendicancy, holds far too true of our present sects. With private charity no law can interfere, and we can do nothing but appeal to the discretion of individuals. With testamentary charities it is otherwise.

We are far yet from the time when so beneficial a measure will be possible, but I trust that we are rapidly approaching the time when the whole of these pernicious charities will be swept away. We have in this country carried respect to the wishes of past generations to an extent simply irrational. The laws of property are a purely human institution, and are just so far defensible as they conduce to the good of society; yet we maintain them to the extent of wasting and misusing no inconsiderable fraction of the land and wealth of the country. It would be well worthy, I think, of Mr. Goschen's attention, whether all small parish charities might not be transferred to the care of the guardians of the poor, so as to be brought under the supervision of the Poor Law Board, and distributed in accordance with sound principle. I should refuse to see in all such public endowments

any rights of private property; and the State which undertakes the ultimate support of the poor is bound to present its own efforts to reduce pauperism from being frustrated, as they are at present.

And while speaking of charities, it is impossible to avoid noticing the influence of medical charities. No one could for a moment propose to abolish hospitals and numerous institutions which are absolutely necessary for the relief of accidental suffering. But there is a great difference between severe accidental disease or injury and the ordinary illnesses which almost every one will suffer from at various periods of his life. No working man is solvent unless he lay by so much of his wages as will meet the average amount of sickness falling to the lot of the man or his family. If it be not easy to determine this amount, there are, or may be, sick clubs which will average the inequalities of life. In so far as trades unions favour the formation of such clubs, they manifest that spirit of self-reliance which is the true remedy of pauperism.

But the wealthy classes are, with the best motives, doing all they can to counteract the healthy tendencies of the artisans. They are continually increasing the number and resources of the hospitals, which compete with each other in offering the freest possible medical aid to all who come. The claims of each hospital for public support is measured by the number of patients it has attracted, so that, without some general arrangement, a more sound system is impossible. Hospitals need not be self-supporting, and in cases of really severe and unforeseen suffering they may give the most lavish aid; but I conceive that they should not relieve slight and ordinary disease without a contribution from those benefited. As children are expected to bring their school pence, though it be insufficient to support the school, and as Government has wisely refused to sanction the general establishment of free schools, so I think that every medical institution should receive small periodical contributions from the persons benefited. Arrangements of the kind are far from uncommon, and there are many self-supporting dispensaries, but the competition of free medical charities has, to a great extent, broken them down.

The importance of the subject with which I am dealing can only be estimated by those who have studied the statistics of London charities prepared by Mr. Hicks and published in the 'Times' of 11th February, 1869. It is much to be desired that Mr. Hicks, or some other statistician, would extend a like inquiry to all parts of the United Kingdom, and give us some notion of the amount of money expended in the free relief of the poor.

Closely connected with this subject is that of the poor-law medical service. Admirable efforts are being made to improve the quality of the medical aid which all persons sufficiently poor can demand, and some unions have already erected hospitals almost perfect in their comfort and salubrity. It will be conceded by every one that those sick persons whose charge is undertaken by the public ought to be treated with care and humanity. Where medical aid is given at all, it ought to be good and sufficient. But the subject seems to me to be surrounded with difficulties, out of which I cannot find my way. The better we make the poor-law medical service, the more we shall extend and deepen the conviction, already too prevalent, that the poor may make merry with their wages when well and strong, because other people will take care of them when sick and old. We thus tend to increase and perpetuate that want of self-reliance and providence which is the crowning defect of the poorer classes. In this and many other cases it seems as necessary as ever that our humane impulses should be guided by a stern regard to the real results of our actions.

I now turn to a subject which must come prominently before our Section. I mean the future financial policy of the kingdom. We are now at a most peculiar and happy epoch in our financial history. For thirty years or more a reform of the tariff has been in progress, and it is only a year since the last relic of the protective system was removed by Mr. Lowe's repeal of the small corn-duty. One great scheme is thus worked out and completed; henceforth, if duties are remitted, it must be on a wholly different ground—as simple remission of revenue, not as the removal of protective duties which benefit some to the injury of others. It might well be thought difficult to overlook the difference between a tax for revenue purposes and one for protective purposes; and yet there are not a few who seem not

to see the difference. We are still told that there is no such thing as free trade, and that we shall not have it until all custom-houses are swept away. This doctrine rests, however, upon a new interpretation of the expression free trade, which is quietly substituted for the old meaning. Cobden, however much he might be in favour of direct taxation, took care to define exactly what he meant by free trade. He said:—

"What is free trade? Not the pulling down of all custom-houses, as some of our opponents try to persuade the agricultural labourers. Our children, or their offspring, may be wise enough to dispense with custom-house duties; they may think it prudent and economical to raise revenue by direct taxation; we do not propose to do that.

"By free trade we mean the abolition of all protective duties.

"We do not want to touch duties simply for revenue, but we want to prevent certain parties from having a revenue which is to benefit themselves, but advantage none else; we seek the improvement of Her Majesty's revenue."

Let us, then, candidly acknowledge that in Cobden's sense free trade is actually achieved. Any one the least acquainted with our revenue system knows with what skill our tariff has been adjusted by Peel, Gladstone, and Lowe, so that the articles taxed should be of entirely foreign production, or else the customs duty should be exactly balanced by an excise duty. We have now a very large revenue of about forty millions, raised by customs or excise duty on a small number of articles, with the least possible interference with the trade of the country. A very large part, too, is raised upon spirituous liquors, the consumption of which we desire, on other grounds, to reduce rather than encourage.

For the future, then, the remission of customs duties will be grounded on other motives than it has often been in the past; and it becomes an open question whether there are not other branches of revenue far more deserving attention. It must not be supposed that foreign trade is to be encouraged before everything else. The internal trade and industry of the country is at least equally deserving of attention; and it may be that there are stamp-duties, licence-duties, rates, or other taxes which, in proportion to the revenue they return, do far more injury than any customs duties now remaining. It is impossible, for instance, to defend the heavy stamp-duty paid by the articled clerks of attorneys on their admission; and, if I went into detail, it would be easy to point out scores of cases where the attention of the Chancellor of the Exchequer is needed.

I may point to local taxation especially as a subject requiring attention, even more than any branch of the general revenue. Until within the last few years the importance of the local rates was to a great extent overlooked, because there were no adequate accounts of their amount. The returns recently obtained by the Government are even now far from complete, but it becomes apparent that at least one-fourth part of the whole revenue of the kingdom is raised by these neglected rates and tolls. Their amount is more than equal to the whole of the customs duties, upon the reform of which we have been engaged for thirty years. Nevertheless we continue to allow those rates to be levied substantially according to an act passed in the reign of Queen Elizabeth. Whole classes of property which were unrated three centuries ago are unrated now, and it will be a matter of great difficulty to redress in an equitable manner inequalities which have been so long tolerated. The subject is of the more importance because there is sure to be a continuous increase of local taxation. We may hope for a reduction of the general expenditure, and we shall expect rather to reduce than raise the weight of duties; but all the more immediate needs of society, boards of health, medical officers, public schools, reformatories, free libraries, highway boards, main-drainage schemes, water-supplies, purification of rivers, improved police, better poor-law medical service—these, and a score of other costly reforms, must be supported mainly out of the local rates. Before the difficulties of the subject become even greater than they now are, I think that the principles and machinery of local taxation should receive thorough consideration. At present the complexity of the laws relating to poor rates is something quite appalling, and it is the herculean nature of the reform required which perhaps disinclines financial reformers from attacking it. Several most able members of the Statistical Society have, however, treated the subject,

especially Mr. Frederick Purdy, Professor J. E. T. Rogers, and Mr. Dudley Baxter. The recent partial inquiry by a select committee has chiefly served to prove the extent and difficulty of the reform which is needed.

We have considerable opposition raised to customs and excise duties, because they are indirect taxes; but the fact is, that direct taxation is practically impossible. Careful examination shows that it is difficult to draw any clear distinction between taxes in this respect. There are few or no direct taxes borne only by those who pay them. The incidence of the local rates, for instance, is an undecided question, but I do not doubt that they fall to a considerable extent indirectly. The incidence of the stamp-duties is almost wholly indirect, but defies investigation. The income-tax no doubt approaches closely to the character of a direct tax, but it has the insuperable inconvenience of being paid by the honest people and escaped by the rogues. I am inclined to look upon schemes of universal direct taxation as affording much scope for interesting speculation, but as being, in practice, simply impossible.

I have another point to urge. Is not the time come when the remission of taxes, whether of one kind or another, may properly cease to be a main object? The surplus revenue of future years will doubtless be more than sufficient to enable the Chancellor of the Exchequer to reform or abolish those small branches of internal revenue which occasion far more inconvenience and injury than they are worth. There will still, should war be happily avoided, remain a considerable surplus, and the question presses upon us, Shall this revenue be relinquished, or shall it be applied to the reduction of the national debt?

In considering this subject, I may first point out that there probably exists no grievous pressure of taxation, and no considerable inequality as regards the several classes of the people. We are now able to estimate, with some approach to accuracy, the actual proportion of income which is paid by persons of different incomes. The accounts now published by Government, and the labours of several eminent statisticians, especially Professor Leone Levi and Mr. Dudley Baxter, permit us to make this calculation. The most recent addition to our information is contained in an elaborate paper read by Mr. Baxter before the Statistical Society in January 1869, and since published in the form of a volume. Mr. Baxter has, with great industry and skill, collected a mass of information concerning the habits of persons in different classes of society, which he combines with the published accounts of the revenue and with the statistics of income previously estimated by himself and Mr. Leone Levi. Both he and Professor Levi come to the conclusion that the working classes, so long as they make a temperate use of spirituous liquors and tobacco, pay a distinctly less proportion of their income to the State, and even intemperance does not make their contribution proportionally greater than those of more wealthy persons.

It happens that, before I was aware of Mr. Baxter's elaborate inquiries, I undertook a similar inquiry on a much more limited scale, by investigating the taxes paid by average families spending £40, £85, and £500 a year. My conclusions, as might be expected, were not exactly coincident with those either of Mr. Baxter or Professor Levi; yet there was no great discrepancy. I conceive that families of the classes mentioned, consuming moderate quantities of tobacco and spirituous liquors, all pay about 10 per cent. of their income in general or local taxation, allowance being made for the recent reduction of the sugar-duty and the repeal of the corn-duty. But there is this distinction to be noticed, that the taxation of the middle classes is mostly unavoidable, whereas at least half the taxation of the poorer classes depends upon the amount of tobacco and spirituous liquors which they consume. Families of artisans or labourers abstaining from the use of these stimulants are taxed very lightly, probably not paying more than 4 or 5 per cent. of their income. Now, while many men are total abstainers and many are intemperate, I think we cannot regard the taxes upon stimulants as we do other taxes. The payment of the tax is voluntary, and is, I believe, paid without reluctance. The more we thus investigate the present incidence of taxation, the more it seems inexpedient to proceed further in the reduction of the customs and excise duties. The result would be to leave by far the larger mass of the people almost free from any thing but local taxes, and to throw the whole cost of Government upon the wealthier classes, and especially those who have tangible property.

But I venture to raise another question. I doubt whether the remission of taxation does as much good at the present day as it would at a future time. There are comparatively few signs that the wages of the working classes, even when sufficient, are saved and applied really to advance the condition of the recipients. All is expended in a higher scale of living, so that little permanent benefit results; and when bad trade comes again, there is as much distress as ever. It is only with the increase of education and temperance that the increase of wages will prove a solid advantage. Thus, when the really hurtful taxes are removed, it by no means follows that the further remission of taxes leads to the profitable expenditure of income. The money may be spent in a way far more profitable to the whole nation than it will be spent by those whose taxes are remitted.

I am glad, on this and many other accounts, that the propriety of reducing the national debt is beginning to be very generally recognized. The question was ably raised by Mr. Lambert during the recent session, and, both in the House of Commons and in the newspaper press, many strong opinions were expressed in favour of reduction. In fact, there was almost a general feeling that Mr. Lowe's small measure of reduction was altogether inconsiderable compared with our opportunities and the greatness of the task before us. During every interval of peace we ought to clear off the charges incurred during the previous war, otherwise we commit the serious error of charging to capital that which should be borne by income. If a railway company needs periodically to renew its works, and charges all the cost to capital, it must eventually become insolvent; so if at intervals we require to maintain the safety and independence of this country or its possessions by war, and do it all by borrowed money, we throw the whole cost of our advantage upon posterity. If, indeed, one great war could free us from all future danger we might capitalize the cost and leave it as a perpetual mortgage upon the property of the country; but if the effect of any war wears out, and we are liable to be involved in new wars at intervals, then we cannot fairly or safely go adding perpetually to the mortgage upon the national property. The wars at the commencement of this century have secured for us fifty years or more of nearly unbroken peace, and yet at the end of this period of ever-advancing wealth, the great debt stands almost at the same figure as at the commencement. We enjoy the peace and leave our descendants to pay its cost.

If it be said that this country is now far wealthier and more able to endure the annual charge of the debt than ever before, I would point out that the expense of war is also greatly increased. If we consider the cost of the Abyssinian Expedition, or the vast debts which other nations have lately or are now incurring, it is evident that we may have in a great war to incur hundreds of millions of debt, or else relinquish our prominent position. Let us hope that such calamities will be spared to us, but let us not suppose that we may avoid them by being negligent and unprepared. It is not many months since Mr. Lowe declared that we must maintain our system of taxation substantially as it is, in order to supply revenue adequate to possible emergencies. The wisdom of his view is already apparent; but I hold that he should have gone further, and strengthened our hands by a measure for the reduction of the debt worthy of his boldness and the surplus at his command. But the fact is, that little can be done in such a matter by any minister unless he be supported by a strong public opinion.

The remarks which I most wished to make are now completed, and there only remain one or two minor topics to which I will more briefly allude.

The excessive mortality in great towns seems to demand more close attention than it has received. For many years Liverpool stood at or near the top of the list as regards mortality, but by strenuous efforts it has been rendered more healthy. Manchester, on the other hand, although often considered the best paved, best watered, and in some other respects the best managed town in the country, has lately taken a very high or even the highest place as regards mortality. In Salford, too, the death-rate has steadily grown in recent years. It would seem as if we were entirely at fault, and that all our officers of health, sanitary commissioners, and the improvements of science and civilization cannot prevent nearly twice as many people from dying as would die in a healthy and natural state of things.

Within the last few months attention has been drawn to this subject by a pro-

longed discussion in the 'Manchester Guardian.' It was occasioned by Mr. Baxendell, who brought before the Manchester Literary and Philosophical Society certain statistics tending to show that the mortality of Manchester was not due to any peculiar excess in the rate of infantile mortality. It was an old opinion that in a manufacturing town like Manchester, the children are neglected while the mothers are employed at the mills; but Mr. Baxendell showed that the deaths of infants under five years actually bear a less proportion to the whole number of deaths than in any other of the large towns. This conclusion was somewhat severely criticized by the Medical Officer of Health for Salford, and by Dr. Ransome and Mr. Royston, of the Manchester Sanitary Association. The latter gentlemen pointed out that the true mode of computation is to compare the deaths of infants with the number of infants living, and the deaths of adults with the number of adults. But even when calculations are made in this manner it still turns out that the adult mortality of Manchester is as excessive as the infantile mortality. Manchester mothers are thus exonerated from the charge of neglect, but at the same time a most important and mysterious problem is left wholly unsolved.

Our perplexity must be increased when we consider that Liverpool and Manchester, though both very unhealthy towns, are quite contrasted as regards situation and the kinds of employment they present. If we compare Liverpool with other sea-ports, such as Bristol, Hull, and London, it is found to exceed them all considerably in mortality. Bolton, Bury, Preston, Stockport and other towns have more women employed than Manchester, comparatively speaking, yet they are more healthy. The size of the town, again, is not the chief cause, for London, though many times more populous than any other town, is decidedly healthy. The sites of the towns do not give any better solution of the difficulty, London having probably as unhealthy a site as any of the other large towns.

I am surprised that more attention has not been drawn to the probable influence of a poor Irish population in raising the death-rate. It occurred to me that the great towns which are most unhealthy agree in containing a large proportion of Irish, and agree in nothing else which I can discover. To test this notion I have calculated, from the census returns of 1861, the ratio of the Irish-born adult population in all the larger towns of Great Britain. It then becomes apparent at once that the unhealthy towns of Liverpool, Manchester, Salford, Glasgow, Dundee, &c. are all distinguished by possessing a large population of Irish, whereas the healthy towns of London, Birmingham, Bristol, Hull, Aberdeen, &c. have less than $7\frac{1}{2}$ per cent. of adult Irish residents. Sheffield is the only remarkable exception to this induction. It might seem that, in order to confirm this conclusion, I should show the death-rate in Dublin to be very high. On turning to the accounts of the Irish Registrar-General, we find the Dublin rate to be low, but then we find that the Dublin birth-rate is even lower in proportion. In fact the registry system in Ireland gives results so much lower in every respect than those of Great Britain, that we must either conclude the state of population to be utterly different there from what it is here, or we must suppose the registration to be very incomplete. If after further investigation this suggestion should be found to explain the high and mysterious mortality of many towns, it will, I think, relieve us from some perplexity, give us more confidence in sanitary measures, and point out exactly where most attention is needed.

The next two or three years will be a time of great interest to statisticians, on account of the approaching census of 1871. We shall soon possess data which will assist us in many investigations, and enable us surely to estimate many of the changes in progress.

There is only one suggestion concerning the census which it occurs to me to make, namely, that it ought to be taken in as nearly as possible a uniform manner in all the three parts of the United Kingdom. It need hardly be pointed out that the value of statistics almost entirely depends upon the accuracy and facility with which comparisons can be made between different groups of facts, and a very slight variation in the mode of making the enumerations of the census or tabulating the results will lead to error, or else render comparison impossible.

Reasons, the force of which I cannot estimate, have led to the establishment of distinct registry-offices in Edinburgh and Dublin. Not only are the ordinary re-

ports concerning births, deaths, and marriages drawn up independently in the several offices for England, Scotland, and Ireland, but even the census is performed by the separate authorities in the three kingdoms. Consequently we have really three censuses and three reports, and at least in 1861 the tables were constructed to a great extent in different modes in these reports. Thus there is a total want of that unity and uniformity which, in a scientific point of view, is indispensable. If there is one thing more than another which demands perfect unity and centralization, it is the work of the census and the Register Office; but if we cannot have one central office, let us hope that the several Registrar-Generals will cooperate so as to produce the nearest approach to uniformity in the census. The different territorial divisions and arrangements may require some modifications in the mode of enumeration, but except in this respect, there should be perfect identity.

I should like to direct your attention for a moment to the very copious and excellent statistical publications with which we are now furnished by Government. Owing partly to the prejudice against blue books, and partly probably to the ineffective mode of publication, the public generally are not aware that for the sum of *8d.* any person can obtain the Statistical Abstract of the Board of Trade, containing an admirable selection from the principal statistics of the country during the preceding fifteen years. For a few shillings, again, may be had the 'Miscellaneous Statistics' of the Board of Trade, furnishing a wonderful compilation of facts concerning three recent years, though I wish that this information could be brought more nearly up to the time of publication.

By degrees a considerable amount of system has been introduced into our parliamentary papers. They have always been sufficiently copious—rather too copious in fact; but until the last twenty years they consisted mainly of disconnected and accidental accounts, which were exceedingly troublesome to statisticians, and often of no use whatever. It is from regular annual publications, carried on in a uniform manner, that we derive the most useful information, that which is capable of comparison and digestion. The annual reports which have for some years been issued from various Government departments are the best source of statistics; and I may suggest that there are several public departments (for instance the Mint) which do not yet give any regular annual reports.

I would especially point, again, to the last report of the Inland Revenue Department as a model of what we might desire from other departments. In addition to the usual annual report, it contains an abstract of the previous reports for ten years back, and, what is still more valuable, complete tables of all inland duties from their first establishment, some of the tables going back to the beginning of last century. We are thus provided with a complete history of the inland revenue. I cannot but believe that in many other departments is much valuable information which might be furnished to the public in like manner at a very slight cost.

Under other circumstances I should have had something to say to you concerning international money. Just before the present unhappy war broke out, a Commission in Paris had reported in a manner greatly facilitating the adoption of an international money in the British Empire and in America; at the same time a conference was about to be held in Berlin, which would probably have resulted in some important measures as regards Prussia. Everything, in short, was favourable to the early adoption of a common money; but it need hardly be said that all hope of such a great reform must be deferred until peace is once again firmly established.

Since this Association last met, the great experiment of transferring the telegraphs to Government control has been carried out. The result has been to some extent disappointing. The proprietors of the telegraphs, when negotiating with Government, discovered that their property was about twice as valuable as they had before considered it. The enormous profits which they made out of the sale seem to me to throw immense difficulty in the way of any similar transfer in the future. It becomes, for instance, simply chimerical to suppose that the Government can purchase the railways, which are about two hundred and fifty times as valuable as the telegraphs, and which, if purchased in the same way, would cost considerably more than the whole national debt. The working of the telegraphic department, again, confirms the anticipation that we must not expect from it any

such results as followed the establishment of the penny post. Many people already look forward to the time when the uniform cost of a telegram will be 6*d.*, but I believe that they will be disappointed. They overlook the essential difference that a great number of letters may be conveyed almost as cheaply as one letter, whereas every telegram occupies the wires for a definite time, and requires to be delivered, generally speaking, by a special messenger. Thus, if we are to have the rapid delivery without which telegrams seem to me nearly valueless, the property and staff, and, of course, the expenses of the department, must expand nearly proportionally to the business. A reduction of the rate to 6*d.*, by bringing a great increase of work, would greatly augment the expenses of the department, and inflict a loss upon the nation.

On National Debts. *By* R. Dudley Baxter, *M.A.*

After enlarging on the importance of the subject, the author traced the history of our National Debt, which was fairly started at the time of the Revolution in 1688, when William III. brought over with him that new scientific invention. In 1763 it was £138,000,000. The American war raised it to £249,000,000, and the French war to £861,000,000, from which point, with the interval of the Crimean war, it was reduced, until now it stood at £749,000,000. He contrasted the cost of a year's war with the very small reductions of a year's peace, averaging £2,500,000. The French Debt, originated by Louis XIV. (with the interval of the Revolution, when a great debt was raised and destroyed in a short time), stood at £245,000,000 at the commencement of the Empire in 1852, whence it had risen to £518,000,000. Under the second Empire the increase was £15,000,000 a year, and there had never been a period of reduction. It must be borne in mind, however, that in the middle of the next century the French railways, now valued at £300,000,000, would become national property. In the United States the debt rose from £18,000,000 sterling on July 1, 1861, during four years of civil war, to £551,000,000 on July 1, 1865; but it has been reduced on July 1, 1870, to £477,000,000, or by £15,000,000 a year. He hardly knew which to wonder at most, the increase or the decrease. He believed that the rate of reduction would be continued. Austria, like France, was an empire of uninterrupted deficits. Her debt was now £300,000,000. Russia was one of the States which had run most recklessly and rapidly into debt. The amount was now £300,000,000. The debt of Spain was now £257,000,000. Italy had gone into debt in the most headlong manner, showing an average increase since 1861 of £19,000,000 per annum. Prussia's debt was the least of all the European nations. North Germany had now a debt of £106,000,000, and South Germany £46,000,000, or only £150,000,000 for all Germany, including £15,000,000 on account of the present war; and her costs in the present war were to be paid by France. The Dutch debt in 1869 was £80,000,000, having been reduced for many years at the rate of £1,000,000 per annum, equivalent to £10,000,000 in England. He argued from the whole, that while the commercial countries had steadily reduced their debts, the non-commercial nations had enormously increased theirs. England's position now, compared with that of 1815, was greatly improved compared with other nations. In 1815 she owed £860,000,000 against £600,000,000 united debt of all other countries, whilst in 1870 she owed £749,000,000 against over £2,300,000,000, the combined debts of other countries. He also compared the burden per head of population of the various debts. Germany's debt was 2*s.* 9*d.* per head per annum against ours (17*s.* 5*d.* per head per annum), and the United States debt per annum was much less than ours; and these two nations were our great competitors. He therefore urged a great and speedy reduction of our national debt, in order to lighten the pressure on industry. Holland's sinking fund was worthy of attention. They might appropriate certain taxes sacredly to the reduction of the debt; or they might adopt a resolute taxation, like the United States, but without their protection errors. He approved of terminable annuities as one agent, but did not deem it sufficient. In conclusion he addressed a word of warning to the nations which had so long and so recklessly increased their national burdens.

Middle-Class Schools as they are, and as they ought to be. By C. H. W. BIGGS, *F.R.G.S.*

This paper contained a sketch of some of the failings, with suggestions for their removal, which may be found in our so-called educational system. In reality we have no middle class educational system, every man being at perfect liberty to carry out his own ideas, whether they be good, bad, or indifferent. Many eminent men of undoubted talent have advised the introduction into this country of systems similar to the most complete of those to be met with on the Continent. This would never answer; for the system to be adopted in England must be adapted to native circumstances and insular peculiarities, must be capable of expanding with the growth of education, and of incorporating all that may hereafter be proved beneficial.

Man is necessary to man, and every man ought to fill a sphere wherein he should by his acts benefit the whole community as well as himself. This he will never do whilst imperfectly educated; and although not able to attain perfection, we are capable of aiming at it. One of the first objects of a community, of a nation, should be to insist that the men engaged in educating the rising generation were equal to their task. Whilst, however, the masters in our primary schools are compelled to undergo a long and arduous training, both in the practical and theoretical parts of their profession, any one is allowed to become a teacher of the great commercial class. Again, some means should be taken to ascertain whether the instruction given was such as to fit the pupils for their future positions. This could be best done by a system of Government supervision and examination, as no other body would be equally unbiassed. An annual blue book could be issued, containing the reports of such examinations, together with suggestions for better achieving what is required. There ought to be some means provided whereby talented students should not be compelled to leave their studies just at the time when most progress was made, but should be able to get the best education the country could give. Briefly, then, we require a system to train and ensure the competency of the masters, and to ascertain that their duties are efficiently performed.

On the Economy of Large and Small Farms. By WILLIAM BOTLY.

First, as regarded the interest of the landed proprietor.

Secondly, as to that of the tenant.

Thirdly, with reference to that of the labourer; and

Fourthly, as to which are the most advantageous *nationally*.

After a tabular statement of the acreage, rent, buildings, capital, &c. of various sized farms, with extracts from the survey of Belgium, by Dr. Voelcker and Mr. H. M. Jenkins, F.G.S., also of Mr. Howard, M.P., and others, the author gave his own, from personal observation in various parts of the United Kingdom, France, &c.

In conclusion, the author observed that he was of opinion (though he would by no means have farms all of one size) that large rather than small were most beneficial to the landlord, tenant, labourer, and nation at large.

On the Duties of the Government of India and of the Merchants of England in promoting Production in India. By GEORGE CAMPBELL, *D.C.L.*

The writer said that he fully recognized that it was the duty of the Government in India, and of the collectors and other officers, to promote the productions of the soil in India by every means in their power. The point to be aimed at was not so much an increase in the area of production as in the productive powers of a given area. In India the Government was the great head landlord, and the collectors were the agents of the great State landlord, and ought to perform a landlord's duties. They had created native landlords, but to suppose that they would perform the duties of a landlord was one of the anachronisms which we English were apt to cling to in the face of fact. The farmers (the ryots) were, in truth, good

farmers, but they were all on a small and humble scale, and they had not the education or information to enable them to adopt scientific improvements. He believed it to be wholly and absolutely incorrect to represent them as too conservative to improve. Show them the means of raising better crops and they would readily adopt them. It was, in his opinion, the duty of the collector of a district to promote agricultural improvements in every way in his power. All that Government had been able to do was to facilitate traffic. The secret of improving our Indian cotton cultivation had not been discovered. Government had sent out practical Scotch gardeners, but he doubted if they would have very rapid success. In his opinion Government made a great mistake in ceasing to maintain a special college for the education of the Indian civil servants. The present examinations were a mistake; the young men were crammed as for a literary examination, and had very little practical knowledge. He especially referred to their ignorance of arithmetic. India, too, was too much overridden by the legal system. It was not enough to administer India by a rigid system of law. The Indian civil servants should be more trained for executive government, with a knowledge of agriculture and other matters. He approved of a department of agriculture in India. He would also advocate security of tenure in India, especially in the new settled districts, many of which were well suited for agriculture, and which would lead to their development. As to the management of the natives, they were much more easily led than driven.

On the Tobacco Trade of Liverpool. By J. S. Campbell.

The writer traced the history of the trade from its commencement, which was in the year 1665, and stated that by the year 1700 the tobacco trade with Virginia had taken the lead of all the others, the principal merchants of the town being then engaged in it. During 1770 the total imports of tobacco in Liverpool amounted to 5447 hhds. In 1788 the first tobacco warehouse was built in Liverpool, on the east side of the King's Dock, and was calculated to hold 7000 hhds. The steady growth of the trade, however, soon rendered increased accommodation necessary, and in 1814 a larger structure was built, which had since been enlarged to twice its original size, and was calculated to contain 20,000 hhds. From 12,928 hhds. in 1823 the imports rose to 16,583 hhds. in 1869; the largest stock in warehouse at any one time being at the end of 1865, when it reached 27,820 hhds. Of the total hogsheads imported in Liverpool, about one-fourth (perhaps a little more) was cleared for manufacture in the town, one-fourth was sent to Ireland, one-fourth coastwise to various ports in England and Scotland, and the remainder was exported to various foreign ports. The above figures refer only to American tobaccos; of other growths there were imported in 1869, 3709 bales and packages. Liverpool had fully one-half the stock of American tobacco in the United Kingdom, and the business was at present in the hands of eight brokers and about seventy importers.

He described the business as an exceedingly quiet and regular one, the brokers and importers, as a rule, sticking to their fixed and antiquated practices, and obstinately resisting any attempt at innovation.

The paper concluded with some remarks on the extent of tobacco manufacture in Liverpool, and the desirability of a more extensive introduction of female labour into this branch of industry.

Proposition for a Census of Local Names. By Hyde Clarke, *F.S.S.*

The object was to enumerate in each enumeration district all known names of towns, hamlets, farms, fields, rivers, hills, commons, &c., in extension of the materials in the Indexes to the Censuses of 1841, 1851, and 1861, so as to give better information as to the distribution of English names (with their forms of Frisian, Norse, &c.), and of Celtic, with their forms of Welsh, Cornish, Irish, Erse, and Manx.

On the Decline of Small Farmers in Yorkshire and Lancashire, the Cause and Effect. By J. Walter Ellis.

The decline in numbers may be traced to three causes, want of capital, high rents, and dear labour. Farming, to be now successful, is a question of capital and intelligence. Many farms in Yorkshire and Lancashire are now made into one, three and four or five small farms being let as one farm, the buildings pulled down, the fields made larger by removing many fences, so that machinery may be available; then a man with intelligence and capital takes it, and it is better farmed, produces more, and adds greater profit to the national weal by the use of machinery. As land passes into commercial hands, the rents are in many cases nearly doubled, as a commercial man expects higher interest for his money: often one of his clerks or his cashier is appointed agent or steward over the estate, who has little sympathy with the farmers; and invariably the smallest farmer feels the effects first, and the consequence is he removes to the large towns, where he is well paid for his labour (3*s*. 6*d*. to 4*s*. per day). Many labouring men have made this summer, in towns and works near town, at 6*d*. per hour, as much as £2 10*s*. per week. The author knows three, who were once small farmers, who have had £2 per week in the neighbourhood of Bradford this summer, and whose families of grown-up daughters make from 18*s*. to 25*s*. per week as weavers in the factories. The small farmer is better off as a labourer in the town than the middle-size farmer is in the country. The large towns are ready to absorb all the surplus labour from the country, by the centralizing of works, the use of steam-power, and the continual increasing producing power of the English manufacturer: and the cry is for more labourers from the country, as the town labourers are being fast used up; by imbibing the vices of the town they soon become as weak as the old residents of the town.

Our Navy. By Frank P. Fellowes, *F.S.A., F.S.S.*

This paper pointed out that the supremacy of England on the sea was the means of ensuring the freedom of all seas to all nations. Our holding Malta, Gibraltar, and our numerous other foreign dockyards and stations, our fleets scattered throughout the world, ensured the freedom of the Mediterranean, Black, and other inland seas, and prevented their becoming the appanage of any great power; freed the Indian archipelago, the Chinese, Japanese, and other seas from pirates; and, in fact, caused all seas to be open to the ships of every nation without passport or toll legally or illegally levied. Our present maritime position was therefore as great a benefit to other nations as to England itself. Mr. Fellowes stated that a national dockyard, in his opinion, should be, as it were, a little kingdom in itself, in which (should it be cut off from the outer world) it could furnish men, materials, and appliances to build, equip, repair, man, and provision ships.

The question as to where dockyards should be placed, and how many we should have, was a political and national, rather than an economical question. These points should be decided, therefore, on political and national grounds, and not from an economical point of view. The question of economy comes afterwards; that is, when we have already decided that it is wise and necessary to have a dockyard in a certain position, and it is established, the question of economy properly commences in the management and conduct of the operations of such dockyard.

In speaking of our numerous foreign naval establishments, the author showed that our keeping up Malta, Gibraltar, and other foreign stations was in reality economical, as otherwise we should have to maintain a much larger fleet to be as powerful on the sea.

This paper entered minutely into the question as to the proportionate distribution of money to the various naval services that would ensure the greatest effective force. We give an illustration. The annual expenditure in building new ships is about £1,500,000; the annual total expenditure for all naval services is about £10,000,000. If by doubling our expenditure of £1,500,000 for new ships we could produce new first-rate iron-clad or other vessels, one of which in effective power would be equal to two of the existing ships of similar tonnage and horse-power, we practically double our naval effective force; that is, we are as efficient

and powerful as if we had expended an extra £1,500,000 in building similar ships to those that exist, and £8,500,000 for the remaining current expenses of the navy, such as paying officers and men, provisions, repair and maintenance of ships, &c.; because if we double the *effective* power of each ship we double thereby the *effective* power of each officer and sailor on board, and all the other current expenditure, such as provisions, wear and tear of ship, &c., for it costs no more to repair, man, and victual a good and efficient vessel than to do the same for a bad and inefficient one. In the first case we double our effective power by an increased expenditure of £1,500,000 annually; in the other we only do it by an increased annual expenditure of £10,000,000. The author then pointed out that the judicious distribution of the money was of much more importance in obtaining great results by a small expenditure than mere cheese-paring of all the services without regard to this important point. "It was with views similar to these that led Mr. Seely and myself to devote our attention mainly to this element of expenditure to make it effective, as otherwise all else is ineffective. The weapon of war, whether a ship or a gun, should be the best that human foresight and ingenuity can devise; and expense on this head is, after all, but a secondary consideration."

In evidence before Mr. Seely's committee the author had given numerous instances occurring in past years, in which the repairs of ships had cost as much or more than similar new ships. Now it was a rough rule with shipbuilders, that an old repaired ship when repaired was worth about half as much as a similar new ship. Hence arose a very large and worse than useless expenditure. The plan that is now adopted to obviate any such useless expenditure is, when a ship requires repairs to have an estimate of the probable cost of such repairs, and it is then decided whether it is wise to repair it at all; if not, she is sold or broken up, it being wisely considered that the first loss is the least. By being careful on these points the Admiralty has more money to expend on new and efficient ships without coming to Parliament for a grant, and we get money's worth for the money expended.

The paper then gave in detail an account of the working of Mr. Fellowes's new scheme of Admiralty accounts, by which, for the first time, the unification of all the Admiralty accounts had been effected, so that the money as voted by Parliament, and disbursed by the Treasury, could be clearly traced into its appropriation to ships and services and manufactures; so that the given cost of such ships and services and manufactures actually balanced the sums disbursed by the Treasury from the votes as granted by the House of Commons.

The author then pointed out that formerly the whole of the dockyards at home and abroad were treated as one great Establishment, so that a ship costing really, say, £80,000 at Devonport, and a similar ship built in the same year at Portsmouth costing £120,000, would each be given as costing £100,000; so that the economy of one yard was made to pay for and to hide the extravagance of the other.

Under the author's system, each dockyard and each manufactory was now treated in the Admiralty accounts as if it were the only dockyard or manufactory the Government possessed, and each had to account strictly. By these means comparisons were instituted which led both to economy and efficiency.

By these and similar means the present Admiralty had been enabled greatly to reduce the annual expenditure for the navy without at all decreasing our naval effective power.

The author concluded by recognizing the great efforts of Mr. Seely and other members of the committee on naval monies and accounts, and by acknowledging the aid and support he had received from Mr. Childers, Mr. Baxter, and Sir Spencer Robinson in carrying out his plans and views.

On the Influence of Price upon the Cultivation and Consumption of Cotton during the past ten years, embracing the period of the American War and Cotton Famine. By WILLIAM B. FORWOOD, *Vice-Pres. Liverpool Chamber of Commerce.*

The author first drew attention to the position of our cotton supply in 1860, the year antecedent to the American war, when our chief source of supply was America,

which in that year produced a crop of 4,675,000 bales; and of our import that year we derived from America 76 per cent., India 16 per cent., Egypt and Brazil each 3 per cent., West India and Turkey under ½ per cent.

The breaking out of the American war in 1861 stopped the import of American cotton, and caused an advance of 150 per cent. in value; and our import gradually increased from sources other than America until, in 1865, it was 1,508,000 bales in excess of 1860, the proportionate supply from various sources being as follows:—America 16·77 per cent., Western India 37·73 per cent., Egypt 12·11 per cent., Brazil 12·35 per cent., West Indies 4·767 per cent., China 5·14 per cent., Bengal and Madras 11·28 per cent. From this it will be seen how quick and how potent was the effect of price in stimulating into activity the inhabitants of almost every tropical country to gain part of the prize that was to be obtained by growing cotton and shipping it to this country.

The author showed that the uncertainty in which the production of cotton in America after the war was shrouded caused very high values to be maintained, although our import in 1866 was only 181,862 bales of 400 lbs. less than in 1860. And to this high range of prices he attributed the wonderful rapidity with which America has been able to overcome the great difficulties arising from the effects of the war, but above all from the abolition of slavery, so that she is now again our great source of supply. He drew attention to the great success that had attended the efforts of Government to extend and improve the cultivation of cotton in India, and the rapid development of cotton-cultivation in Brazil; he showed that as extremes beget extremes, so it is quite probable that three or four years of high prices having recouped the fixed capital embarked in cotton-planting, we may in ten years from the date of the cotton famine have a supply of cotton from 10 per cent. to 15 per cent. larger than we received in 1860, notwithstanding that in the meantime the whole system of cotton-cultivation, both in America and in India, has been transformed. He pointed out that the high prices of 1866, by arresting consumption, enabled a stock to be accumulated in Europe and America, which has permitted the consumption of cotton for three years since to exceed the production by a yearly average of 270,000 bales without seriously advancing values. In turning to the question of the influence of price upon consumption, in 1860 every spindle in the country was fully employed; in 1863 not more than one-third were in work. After reviewing the phases of our cotton-manufacturing industry during the memorable years 1862–65, and of the growth of our other textile manufactures, such as linen, worsted, and woollen, he went on to show the causes of the bad state of trade in Lancashire, which may be summed up in a consumptive power greatly in excess of the supply, while at the same time the high price of cotton fabrics stopped their free consumption; thus while the spindle-power of this country is equal to a consumption of 54,153 bales of 400 lb. weight per week, the actual consumption in 1868 was 47,378 bales, and in 1869 45,268 bales of 400 lb.; it was this deficiency in the supply as compared with the consumptive power, combined with high prices, that produced all the mischief.

He took a very hopeful view of the future. He showed that whereas the spindle-power of Europe and the Northern States of America in 1860 was equal to a weekly consumption of 102,676 bales of 400 lbs., the supply in that year was equal to 113,814 bales of 400 lb.; in 1870 the spindle-power is equal to a consumption of 109,639 bales, and our probable supply equal to 102,557 bales of 400 lb., so that we have at last brought the supply within 6·86 per cent. of the spindle-power, or 371,000 bales of 400 lb.; and the prospects are very fair that this deficiency will be made up during the course of the next twelve months, when we may look for a much lower average in price and the return of a full tide of prosperity to this district.

In conclusion the author drew attention to the value of the Cotton Statistics Act, if the stock were once more adjusted and the quantity of cotton taken by the trade was given weekly as well as the quantity exported and imported.

A Proposed Rearrangement of the Registration Districts of England and Wales, for the purpose of facilitating Scientific Inquiry. By ALFRED HAVILAND.

The author commenced his paper by stating that the registration districts of England and Wales were formed for the general purposes of the Poor-Law Administration, and therefore it could not be expected that they were planned with any view of assisting science; they had, however, done so when in their present crude and artificial form, and it was generally believed among scientific men that if their boundaries were determined on a natural system, the advantages to meteorology, climatology, and other branches of science would be incalculable, and the expense and confusion of constant alterations avoided. Messrs. Keith Johnston had lately been engaged by him in the rectification and completion of the registration maps of England and Wales, for the purpose of insuring extreme accuracy in his basis map of the geographical distribution of disease in England and Wales. This had involved him in a considerable outlay, but through the recommendation of the Registrar-General, the Treasury, seeing the necessity of the work, had expressed their approval of a grant being paid to the author for the expenses incurred. He urged that the artificial system adopted in defining the boundaries of the registration districts had been the cause of all this extra work and expense, and that it had nothing whatever to recommend its continuance; on the contrary, it was the fruitful source of repeated alterations, and would continue to be so whilst it was persevered in. On the other hand, the author showed that were a natural system substituted for the present one, and our country divided into districts regulated by its watershed and river system, we should then have in every district a focus of scientific inquiry, whether it be as to the rainfall, temperature, prevalence or strength of wind, agricultural statistics, the produce of our fields, our mines, or our rivers, or for the purpose of registering the occupations, the diseases, or the deaths of the people. Moreover, such a system would form the best basis map for every future census, and being once established upon a well-considered and natural plan, would do away with the necessity of those eternal alterations which are now year by year going on, to the utter confusion of the scientific student. In France the watershed system is adopted in defining and naming the departments; it is vastly superior to our own, and although its deficiencies are numerous, yet they will act as beacons to us. The author was well aware that such a revolution could not be accomplished under ten years, therefore he urged the necessity of commencing it at once. Should the natural system be adopted before 1881, it would be ready for the census of that year, by which time the Registrar-General will have completed two more decades of mortuary records under the present system, and these, with the one (1851–60) which the author had geographized, will form a most important foundation for all future inquiry.

On the Aptitude of North-American Indians for Agriculture.
By JAMES HEYWOOD, *M.A., F.R.S.*

The writer commenced by explaining how the aboriginal Indians in Canada were placed upon reservations, and how they were governed and controlled. He referred more particularly to the settlement of the Six Nations—Indians in the Tuscarora reserve on Grand River, in the province of Ontario, where the Indians formed among themselves an agricultural society, supporting annual exhibitions of stock and produce, which are assisted by grants from the New England Company, an English corporation founded under Oliver Cromwell, and especially devoted at the present day to the promotion of the welfare of Canadian Indians.

Reports to the Congress of the United States describe the condition of numerous Indian tribes, among whom the Indian inhabitants of reservations near the Pacific Ocean particularly manifest the results of successful agriculture.

On the Umatilla reservation in the north-eastern portion of Oregon, the Indians pay much attention to raising horses and cattle, and are comparatively wealthy. Their crops in 1864 comprised wheat, oats, Indian corn, potatoes, peas, and garden vegetables.

Similar proofs of farming industry were noticed in 1865 on the Yakama reservation, 70 miles north of the Columbia river. About 5000 Indians are located in that neighbourhood, and 1200 acres of land are under Indian cultivation.

The Government have erected for these Indians a good grist- and saw-mill.

A farm is connected with the boys' school, upon which the boys labour a certain portion of their time; the proceeds of their labour are applied towards their support. Agent Willous, who has the charge of the Yakama reservation, neglects no opportunity to give the Indians instruction of a practical character.

Among the inquiries of the Committee of Congress in 1865 respecting Indians, the following question was asked of Brigadier-General James H. Carleton, of the Head Quarters department of New Mexico, at Santa Fé:—

"Is it best that the Indian lands should be held in common or in severalty?"

General Carleton in reply gave it as his opinion "that the Indian land should be held in severalty."

"Surveys should be carefully made, and each family or head of a family should have a part allotted to him.

"The human being, white, red, or black, who plants a tree or a vine, or builds a house, or makes a field or garden, identifies himself with it—loves it; his children are born there, and the associations connected with all these things constitute and give birth to what we call *home* love and home feeling." "We have," observed General Carleton, "taken quite enough from the Indian. Let them have and keep really a home."

On the Statistics of the Contagious Diseases Acts. *By* Berkeley Hill, *M.B., F.R.C.S.*

It was remarked that there are two chief points for statistical inquiry,—the prevalence of these diseases, and the amount of control sanitary regulations exercise over their propagation. The three main varieties of contagious diseases were then briefly described, and the following facts mentioned to show the prevalence of the most important form of these diseases. At Eye hospitals one-fifth of diseases of the eye are from constitutional contagious disease. At the Throat hospital about 15 per cent. have similar origin. Taking the estimate of the medical officer of the Privy Council that $3\frac{1}{2}$ per cent. of the sickness relieved gratuitously in the metropolis is due to the constitutional form of contagious disease, an estimate the author showed to be insufficient, we have even then 28,000 of the working male population of the metropolis alone constantly more or less incapacitated by the constitutional form of disease. It was mentioned also that 16 out of every 1000 who offer themselves as recruits to the army have this form of the disease. A comparison was then drawn between the number of persons who apply for relief from these diseases at the general hospitals of London and that which is treated at the same institutions of Paris; being 6·6 per cent. of those examined by the agents of the Medical Officer of the Privy Council, even allowing a reduction of one-fourth to be made for the proportion of sick persons relieved by the Poor-Law Medical Officers, who do not treat this kind of sickness out of the workhouse. In Paris, of the total sick persons relieved by the general hospitals, the portion with contagious disease was 3·3 per cent. In the Navy and Army the amount of loss from contagious disease has been estimated with approach to exactitude. This loss, for some reason, declined slowly and steadily year by year from 1860 to 1866–67. Since that date the diminution has continued more rapidly where the Contagious Diseases Acts operate, while, where they do not operate, the decrease has been replaced by increase, so that the level of 1860 has been regained at nearly all stations unprotected by the Acts; the entry at the stations protected by the Acts being 58 per 1000 of mean strength of the soldiers, and at the unprotected stations 111 per 1000 for the same form of disease. So, again, the average number of soldiers constantly off duty in 1864, the year the first Contagious Diseases Act was passed, was 19 per 1000 of strength; in 1869 it has fallen in the protected district to 12·6. Still this is more than the loss in the French Army, where it is 11·11 per 1000; the whole loss from these kinds of sickness being equal to $7\frac{1}{2}$ days of the English Army's time, 4 days of the French Army's, and slightly less

than three days of the Belgian Army's services every year. With respect to the soldiers and sailors at Portsmouth, the number of fresh cases in a single week of May 1870 was 17; in the corresponding week of 1864 it was 60. The number of days of sickness in the crews of the home station from contagious disease averaged 99,658 every year between 1861 and 1865, in 1867 it fell to 72,132, reducing the annual money cost from £21,867 to £15,898. To prove that in the general deduction of contagious disease the true constitutional disease has also been lessened, it was narrated that the period of treatment of this form has been greatly shortened among the female patients from 125 to 66 days; and that the form of ulcer, almost always, if not invariably, the prelude of constitutional disease, has been reduced to one half its previous amount in the protected stations, and to one half its present amount at the unprotected stations. That the civil population reaps considerable benefit from these Acts appears from the number of contagious patients admitted into the three workhouses of the Plymouth district, which has been reduced from 151 males and 705 females to 55 males and 167 females in the same length of time; also the percentage of such patients in the Devonport jail was reduced from 4·06 to 1·89 per annum.

The effect of the Acts on the moral and social condition of the women subjected to them was alluded to. The matron of the Portsmouth Home for abandoned women stated that of 1114 such persons living in Portsmouth in 1869, 161 left the district, 94 are now living with their friends, 43 have married, 30 have entered the home, 10 are in service, 24 in the workhouses, 12 have died, 10 have returned to their husbands, leaving 730 still in the town, or 384 less than last year. In the report of the Commissioner of Metropolitan Police, it is stated that 7766 women have been brought under the Acts in various towns, of whom only 3016 remain; hence, to quote from Dr. Lyon Playfair's speech in the House of Commons, "4750 no longer practise their vocation in these towns; of the remainder, 107 have died, 385 have married, 451 have entered homes, and 1249 have been restored to their friends. In short, 27 per cent. are known to have returned to a respectable life. Thus 32 per cent. have left the stations, many doubtless to pursue their miserable career elsewhere, but many also, as the police believe, and as in charity we are bound to hope, to return to their own homes." The places of resort of these persons had likewise diminished in the Plymouth district from 358 in 1864 to 131 in December 1869.

Intemperance, purely with reference to Liverpool. By the Rev. John Jones.

This was simply a statistical paper showing the varied ravages made by strong drink upon a community, and contained the following facts:—Liverpool did not owe its intemperance to its being a seaport, as in the year 1869, out of a total of apprehensions for drunkenness amounting to 24,614, there were but 1997 belonging to the canal, the river, and the sea, leaving an excess of 18,617 for other avocations.

The Hospitals and Dispensaries during the year 1869 had 72,278 cases, at an expenditure of £22,088 7*s.* 1*d.* Three Dispensaries during thirty years received a total of 1,250,000 patients, at a cost of about £100,000. The main source of all this suffering is drunkenness—engendering disease, accidents, and poverty. Thus the great bulk of cases in the Hospitals are tolerated as "*accidents*;" for example, a Hospital with 3781 cases during the year had 2893 of these as accidents; and it has been computed that out of a total of accident cases amounting to 19,378, not less than 12,030 of these were the result of intemperance.

Pauperism was thus shown. In Liverpool there are three workhouses having a total of 4714 inmates, while outdoor relief was given to 9998 persons in one week in one of the Unions, and to 22,183 persons and 2537 families respectively during the year in the two other Unions; while medical relief was given in the one Union at the rate of 100,000 cases per annum, and in the other Unions to 5864 cases and 1790 families respectively. In one of the Unions there were in a given week 589 lunatics, 391 cases being admitted during the year. The expenditure on behalf of all these paupers and lunatics amounts to upwards of £250,000 per annum, which, but for intemperance, might nearly be altogether uncalled for. In addition to parish relief, a Voluntary Society has, during the past six years, re-

lieved 120,638 cases of distress at a cost of £16,560 16*s.* 8*d.*, together with nearly 1,000,000 quarts of soup; while 7000 dinners have been provided weekly for starving children in the several Ragged Schools.

Criminal intemperance was thus shown. During the past year 23,458 cases of drunkenness passed through the hands of the police, the number having doubled as compared with the year 1861: 3343 men and 2300 women were tabulated as "habitual drunkards;" some of whom were in custody during the year 15 and 18 times. Out of 2249 resident prostitutes there were 1867 cases of apprehension for drunkenness, the "social evil" and "strong drink" going hand in hand. The majority of drunkards are Irish. Thus, while there were natives of Scotland only 882, of Wales 645, of foreign lands 512, of Ireland there were 7947. Among the drunken there were 16,503 lodgers to 3166 householders,—housekeeping and drunkenness unable to flourish together. In the town there were 1182 houses of bad character, while 20 murders, 15 manslaughters, 106 cases of stabbing, &c., took place during the year. Out of 17,529 cases of drunkenness, 10,934 were more or less educated. The year 1870 is the worst for drunkenness recorded in the annals of the police. Out of 18,303 cases of drunkenness there are 8536 women. The Borough Gaol, erected at a cost of £100,000, is become too small. The annual cost to the Borough of intemperance is computed to be £375,000.

During a period of 36 years 21,300 cases of death were investigated in the Coroners Court; 85 per cent. or 18,105 of these were attributed by the late coroner to drink. The present average number is about 900 cases per annum, 300 of which are children under 5 years, about 140 of these being annually suffocated by drunken parents.

There are, as accounting for all the foregoing, 3579 alcoholic establishments of all sorts, to about 500 only of bakers' shops. Out of 770 employes in one firm 499 were Scottish. One drunken case per day to each public house amounts to 195,000 per annum.

The paper advocated the rights of the people to put down all public houses by a sufficient majority so deciding.

On the Impolicy, on economic grounds, of converting the National Debt into Terminable Annuities. By Dr. THOMAS DE MESCHIN.

On the Compulsory Conversion of Substantial Leaseholds in Towns into Freeholds. By Dr. THOMAS DE MESCHIN.

On the Policy and Provisions of a Patent-law. By R. M. PANKHURST, *LL.D.*

After stating and defining at length the two classes of objections to the policy of a patent-law (viz. that protection to inventions is vicious and wrong; secondly, that though some protection may be desirable, it ought not to be in the nature of a legal protection), the author went on to state the considerations of gain which should induce the creation of a right of property in inventions. They were, that inventions might be more largely and rapidly made, become sooner and more thoroughly perfected, be speedily made and fully disclosed, be more energetically and successfully brought into general use, and finally, after the legal right in them had been duly determined, that they might become the common property of society. With regard to definition of terms, an invention considered as a subject of legal protection was an application of knowledge in general of the laws of nature, expressed in the form of a new and useful process. A patent right in view of legal protection was the creation of a limited right of property in a new and useful process. These, the author submitted, were sufficient reasons. Upon the question of right, the whole essence of the case lay here: Was it the best way to promote invention and improve manufactures to give the inventor a limited right of property in his invention? If so, these objects were the reasons, the causes of the creation of the right of property, but the source of the right itself was the act of the legislation. The objection that a patent-law was a monopoly the author met by the argument that a patent-right

was not a monopoly. A monopoly was a protection to an existing mode of manufacture or industry, a means to keep in the possession of a few and to injuriously limit existing property; while a patent-right related to something before unknown, but now called into existence and supplied for the use of man. The views of Mr. Macfie and others, who hold that inventors were the creditors of the nation, and deserved national compensation, were next noticed; and he argued that such an arrangement, though it might appropriately form a complement to a patent-law, could never be fully regarded as a substitute for a patent-law. A patent-law, while giving an adequate stimulus to inventions, also secured, during the period over which the right of property existed, that it should be so limited by the terms of its creation as to give the minimum of interference with the freedom of manufactures with a maximum of advantage to inventors and the public. The specification by means of which were determined the questions of utility, novelty, and invasion, next came under notice. This point went to the root of the essential difficulties of a patent-law. Issues in patent causes were principally questions of construction, and it was obvious that the instrument upon the true construction of which the decision of these issues depended should be framed with the utmost care and consideration. The practical evils of the present system were:—(1) the indiscriminate granting of patents; (2) the want of accuracy in describing the nature and limits of the rights secured by the patent; (3) the cost, vexation, and unsatisfactory character of the trials of patent causes. The remedies which he suggested were twofold,—suggestions for the efficient working of the existing law, and the introduction of additional provisions, both of constitution and administration. The proposed remedies might be thus classified:—1, conditions precedent to the granting of patents; 2, provisions to secure accuracy of description and definition; 3, conditions precedent to litigation; 4, provisions in regard to the trial of patent causes. With regard to the first point, the present function of the law officers of the Crown should be either absolutely abolished or essentially modified. Next, the grant of a patent should be preceded by an examination by competent examining officers. The result of that examination should be made in the form of a report, and, if favourable, a grant should be at once made; if unfavourable, there should be the right of appeal. On the second point, the specification, which was the patentee's charter, should be reported upon by competent officers. On the third point, prior to the institution of proceedings for infringement, the report of an examining-officer should be obtained, based upon the statement of the applicant as to the precise nature and extent of the infringement. On the fourth point, the trial of patent causes should be conducted before a judge sitting with assessors. By such means it was contended that the total amount of litigation would be lessened, and simplicity and efficiency would be given to the administration of the patent-laws. The creation of a limited right of property was expedient, for it was capable of precise determination: the duty of the public in regard to it was clearly ascertainable; on the discharge of the duty it was the basis of further improvement, and the time of the cessor of the right was fully shown. The giving to inventors a limited right of property in their inventions would afford them the best security, while, with the least practicable interference with free action, it would confer the greatest advantage upon the public.

On Baths and Washhouses. *By* J. Parry.

Railway Accounts for 1868 *just issued by the Board of Trade, with suggestions for Railway Reform.* *By* John Patterson, *President of the Liverpool Chamber of Commerce for* 1868.

Attention is first directed to the fact that accounts which might have been issued in the spring of 1869 are not issued until after Parliament has risen this year, and therefore fail in the object of supplying statistical guidance for legislation. Nay, not even in the spring of 1870, but only in this week; so that for two sessions the accounts are kept hidden, and the value of publicity is now more historical than practical.

The Report of the Royal Commission on Railways has unhappily failed to receive the consideration from Her Majesty's Government which might have been expected, seeing it was prepared by such high authorities as the Duke of Devonshire, Lord Stanley (Derby), Mr. Lowe, Mr. Glynn, Captain Galton, Mr. M'Clean, and others. It had a large representation of the railway interests; but, notwithstanding, contained many recommendations in the public interest, such as uniformity of classification of goods, definition of terminal charges, revision and reduction of charges for parcels; these reforms to be accompanied by a power of inspection and intervention in the public interest by the Board of Trade, where railways used their powers oppressively. But the recommendations remain a dead letter, and practically, as regards goods and parcels, the railway monopoly charge as they please, competition being prevented by combination and legislation ineffectual from its want of knowledge.

The accounts now before us disclose that in December 1868 England and Wales had 6566 miles of double and 3634 miles of single rails, together 10,200 miles in length, or of single rails 16,766 miles, on which were carried up-passengers:—

			£		s.	d.	
	27,374,061	1st class, paying....	3,366,830,	average	2	5 $\frac{52}{100}$	each.
	70,304,008	2nd ,, ...	4,472,304	,,	1	3 $\frac{27}{100}$	,,
	171,581,244	3rd ,, ...	5,533,778	,,	0	7 $\frac{74}{100}$	,,
107,173 persons =	10,717,300	season-tickets, 100 journeys each	544,928	,,	1	0	,,
	279,976,613		13,917,840				
	Carriages, horses, dogs, and luggage ..		1,312,630				
	Mails		403,626				
			£15,634,096				

Miles travelled by passenger-trains 63,302,374 miles. Distance by each passenger about 16 miles, 1st class; 2nd class 12 miles; 3rd class 8 miles; season-tickets 20 miles.

The charges authorized by multitudinous Acts of Parliament vary from 2*d.* to 3*d.* per mile 1st class, 1½*d.* to 2*d.* 2nd class, 1*d.* to 1½*d.* third (once per day 1*d.*). Practically, charges are 1*d.* 3rd class, 1½*d.* 2nd class, 2*d.* 1st class. These excessive charges are somewhat mitigated abnormally and objectionably by—

Excursion-trains.—These are interpolated in masses, as at Whitsuntide, amongst the ordinary traffic in carriages unfit for the safe and regular conveyance of passengers paying the usual rates. Accidents occur so regularly as to identify the excursion-season with the slaughter-season; whilst the humble condition of the sufferers and the limited intelligence of their surviving relatives minimize the claims for damages, the payment of which is the dead fly in the pot of fragrant ointment poured forth by the eloquent chairman at each railway-meeting.

Return-tickets form the main buffer interposed between the grinding exactions of railway companies and the public impatience. Economy of issue is not one penny each, as that charge would amount to over £1,000,000, the whole traffic charges being less than half that sum.

Free passes stand self-condemned; they are either discounts upon traffic to favoured customers and so unjust to the non-favoured, or are frauds upon the proprietors.

The remedy is a fairly calculated remunerative scale of charges proportioned to the accommodation afforded, supplied regularly, and offering equal terms to all comers, such as

1st class	1*d.* per mile and	2*d.* per ticket additional.		
2nd ,,	¾*d.* ,,	1½*d.*	,,	,,
3rd ,,	½*d.* ,,	1*d.*	,,	,,

The ticket-charge covering all station-expenses and compensating for the fractional cost extra which may attach to short as compared with long journeys.

Luggage, unless in the charge and at the risk of passengers, should be charged: A, *plus* 100 lb., with luggage of value handled by porters, pays 2*s.* 6*d.*; B, *plus* 10 lb. in his own hand, pays 2*s.* 6*d.* A should pay 3*s.* and B 2*s.*

Speed is fairly chargeable extra, ordinary trains 30 miles per hour being assumed

as a basis; 50 per cent. additional may be charged for 50 miles, and proportionately for 40 miles &c., with reductions for delay.

Such charges should yield, the year after their adoption,—

			s. d.	£
40,000,000	1st class	18 miles	at 1 8 each	3,333,333
80,000,000	2nd „	14 „	1 0 „	4,000,000
200,000,000	3rd „	10 „	0 6 „	5,000,000
Additional one-third passengers, 1st-class express				555,555
„ one-fourth „ 2nd „				250,000
„ one-eighth „ 3rd „				156,250
Luggage not now charged—				
1st class				333,333
2nd „				200,000
3rd „				100,000
320,000,000 passengers would pay				13,928,471
Whereas at present 280,000,000 pay				13,917,840

Against the additional cost of carrying 40,000,000 persons may be set off:—

First, the greatly accelerated increase of travelling which would follow.

Second, goods-traffic which would accompany increase of travellers.

Third, the undoubtedly equitable claim for abolition of railway-duty amounting to £448,000 for last year, but which must be imposed until fares are readjusted.

Goods-traffic now exceeds the passenger-traffic in income, having been in 1868:—

	£
33,934,393 tons merchandise paid*	11,760,614
72,698,825 tons minerals paid*	6,066,824
Live stock	618,946
	18,446,384

Two companies dominating the Lancashire district carried $22\frac{1}{2}$ per cent. of the weight $25\frac{1}{2}$ per cent. of the distance, and received $29\frac{1}{4}$ per cent. of the freight of goods and minerals. The conformation of Lancashire explains this: 2,782,582 persons only growing 41,535 acres of wheat, but although within an average distance of 25 miles from Liverpool, charged as if 75 or 100 miles from the Scheldt, are obliged to pay the increased charge levied upon their food, nearly half the wheat imported into England and Wales in the last cereal year having entered the Mersey; the monopoly reigns unchecked. For example, Bristol to Birmingham is 94 miles, wheat is charged 8*s.* 10*d.*; Liverpool to Sheffield, 76 miles, the rate is 15*s.*

The monopoly power is argued for upon the ground of enabling railway companies to compensate districts labouring under natural disadvantages; thus, by charging persons near to Burton a higher rate on beer, they are enabled to send it long distances under cost. The terrestrial providence system may go with the paternal government theory. The second argument is that goods are now carried much more cheaply than before railways were made, to which the answer is obvious; so they should, the cost of transport being reduced.

Again, the companies do not exceed their tariffs, and it is open to the public, or was, to see they are reasonable. The answer is, the tariffs were formed in ignorance, and although intended to protect the public, signally fail; whilst Parliament has reserved to itself a right of revision, and these quasi corporations have no other *raison d'être* than public utility: already the courts of law will enforce the concession of uniform charges to all persons, and places should be similarly treated.

The great argument for high rates is that the total capital shares and loans is £425,161,506, gross receipts £35,226,866, and net receipts £18,092,091 is only $4\frac{1}{4}$ per cent. To this it may be replied, much of this money is borrowed at 4 per cent. Secondly, no such amount of capital has been expended, fictitious shares, issues of stock at 50, 60, and 80 per cent., bonds granted at their face value, but for

* In the accounts for 1869 these items are carefully omitted or confounded, so as to withhold the needful information.

£100,000 where £50,000 cash would have sufficed, the extra price being allowed to contractors who took the bonds. Money expended upon or retained for the construction of lines not yet opened for traffic all fall to be deducted, and would reduce the cost below £400,000,000. Of this sum, much has been expended upon harbours, steam-packets, and other wasteful enterprises; yet, after all, $4\frac{1}{2}$ per cent. is divided*.

It is submitted that this dividend may be rather increased than reduced. Hundreds of thousands of tons of goods are transported for which no return is made; 21 cwt. to 25 cwt. are called a ton, and the gross receipts are now understated, as discounts allowed to certain favoured customers are suppressed; statistical accuracy is thus made impossible, whilst a wide door for frauds is opened.

The suggested remedy of purchase by the State involves a heavy probable spoliation of the tax-payers; but the present system is intolerable, and unless the Board of Trade is endowed by Parliament with additional powers, and vigorously organizes itself to action in the public interest, instead of as at present, and for the last twenty years, interfering between a deeply dissatisfied public and the railway companies, a cry will be raised for purchase. The law of supply and demand cannot apply the remedy; there is not, and in the nature of the case cannot be, competition. The lurid light of the Abergele holocaust has demonstrated that selfishness cannot be relied upon as the safeguard of human life. The public health demands greater facilities of locomotion, and Lancashire wants cheap bread.

On Mechanics' Institutions and the Elementary Education Bill. *By* E. Renals.

Although Mechanics' Institutions had been established for more than a quarter of a century, they had failed to enlist the sympathy of working men. This position was maintained by the statistics which had been supplied to him from some of the largest institutions in the kingdom.

With elementary schools scattered over the country in sufficient numbers to meet the educational wants of the population, one great hindrance to the usefulness of Mechanics' Institutions will be removed. To render these institutions centres of education for working men four things were needed:—1, that the Science Classes which are promoted by the Committee of Council on Education should always be connected with Mechanics' Institutions; 2, that each institution should provide a technical library for the use of workmen; 3, that youths, on leaving school to learn a trade, should be gradually brought into union with an institution by having free admission to a course of technical instruction bearing directly on the employments which it is intended they should follow; and 4, that a portion of the managing body should be composed of working men. It was contended that, as untrained labour was constantly being superseded by mechanical contrivances and inventions, the technical and scientific education thus afforded by Mechanics' Institutions would prepare a larger number of operatives for higher grades of industry; and in this way the capacities of our producing-classes would be improved and elevated.

On the Utilization of Fibrous Cotton-seed. *By* Thomas Rose.

The author said that in such a utilitarian age as this it would be matter for surprise that a vegetable production which should be valuable, and could be supplied by the million of tons, was now wasted. The waste product was fibrous cotton-seed. In America alone more than a million and a half tons of this seed were yearly wasted. This seed was composed of 50 per cent. kernel, which yielded about one-third oil and 50 per cent. husk (shell with fibre adhering), of which the fibre would be one-third. From this he gathered that the now wasted seeds would produce 250,000 tons pure cotton, 250,000 tons oil, and 500,000 tons of cattle-cake, the value of which he estimated at £20,000,000. The husks could be taken to the

* The accounts for 1869 (issued in January 1871) fail to distinguish capital raised for unopened lines, although Companies are required by law to do so.

paper-mill, and the cotton abstracted in such a state as to form a most valuable material for paper. By a process which the speaker described at length, the cotton-fibre could be completely separated from the shell. Compared with esparto grass, the cotton-fibre presented many advantages, chief amongst which was the unfailing supply. He also referred to the value and use of the oil and cattle-cake which the seed would yield.

On the Physical Geography of the United States of America as affecting Agriculture, with suggestions for the Increase of the Production of Cotton. By Robert T. Saunders.

On the Effect which a Mint Charge has upon the value of Coins, to which is added a Proposition for securing at once some of the advantages of International Coinage. By G. Johnstone Stoney, *M.A., F.R.S.*

The value of a gold coin in no degree depends on the proportion of baser metals which may be mixed with its gold; and in this communication when gold is spoken of it is the fine gold which is to be understood, and not those alloys, varying from one country to another, which are called standard gold.

Omitting fractions, the British sovereign contains when new 732 centigrams of fine gold; whence it follows that each centigram of gold, each *cent* as it may be called for brevity, represents about one-third of a penny, the exact equivalent being that every 3·05 centigrams of the fine gold in a new sovereign are worth one penny.

The 25-franc piece contains 725 centigrams of gold, and it has been suggested that our sovereign should be identified with this piece by issuing coins containing only 725 cents of gold; and it is alleged that the value of the new coins would be maintained as high as the sovereign by imposing a mint charge of a little over two pence as a substitute for the 7 cents of gold which are to be withheld. The advocates of the proposal urge in support of their view that, whenever the wants of the country require that more gold shall be coined, it will be necessary to bring to the Mint exactly the same quantity of bar gold as now, in order to procure ten thousand sovereigns.

On the other hand, other financiers are of opinion that the coinage could not be thus treated without depressing its value; although, so far as the author of this communication is aware, they have not pointed out wherein lies the fallacy of the foregoing argument. An attempt is now made to supply this deficiency.

The fallacy seems to consist in regarding the *upper limit* of the value of a coin as the same thing as the value of the coin. A coin is not a commodity of perfectly fixed value, but one which fluctuates between certain limits. The upper limit in London* is sufficiently defined by the weight of bar gold which will procure a sovereign at the Bank†; and if there were no light gold in circulation, the lower limit in London would at present be defined by the weight of bar gold remaining in the sovereign when it just passes out of circulation through defect of weight. It is convenient, though not quite exact in principle, to estimate the interval between these two limits in pence: and estimating it thus, we may say that if coins did not wear, but retained through their whole existence the full weight they have when issued from the Mint, they would have more purchasing power than at present; and again, if they did not wear and had all of them the weight of coins just before they go out of lawful circulation, they would (if there were no light coin in circulation) have less purchasing-power than at present; and that three-halfpence is about the difference between the purchasing-powers of two such hypothetical sovereigns. The purchasing-power of real sovereigns (where no light coin is al-

* In London, because at other stations the problem becomes complicated by fresh considerations—such as the cost of the carriage of the coin from London, the cost of insuring it during its transit, and the loss of interest for the time the transfer takes.

† At the Bank, where coin can be procured for bar gold over the counter, rather than at the Mint, where there would be a delay of about twelve days, the interest during which would have to be taken into account.

lowed to remain in circulation) may be anywhere between these two limits, and in fact differs in different transactions.

To make this clear, consider the case of a shopkeeper who receives a certain quantity of light gold in the year. This occasions him a certain loss, which he looks upon as one of the expenses of carrying on his business, and he recoups himself for it by charging somewhere higher prices for his goods than would otherwise be necessary. In other words, the purchasing-power of money has been lessened.

The effect of taking the seven centigrams of gold out of the sovereign and imposing an equivalent mint charge will now be evident. It would leave the upper limit of the value of a sovereign almost the same as it now is, but depress the lower limit two-pence further down. It would thus produce two highly mischievous effects: it would increase the range of fluctuation from three-halfpence to threepence halfpenny; and it would lower the *average* purchasing-power of a sovereign by about one penny. Neither of these effects could be tolerated: the increase of the range of fluctuations of purchasing-power is one of the worst defects which could be imparted to that commodity which is used to measure the values of other commodities, and the decrease of the average purchasing-power of the sovereign would cause it to cease to be a pound sterling.

We may learn two practical lessons from this discussion,—1st, that the practice of the mints of Great Britain, Russia, and Spain, of coining gold without charge, is very much to be preferred to the practice of other countries in which a mintage is charged, since the imposition of a mint charge increases the range of fluctuation of the purchasing-power of coins: 2nd, that a nation which aims at honesty ought to take effectual means to prevent light gold remaining in circulation; for when light coins circulate it is easy to see that the same two mischievous effects ensue: the range of fluctuation of the purchasing-power of coins is increased, and their average purchasing-power is lowered.

To keep our ideas clear, we should carefully distinguish between three different values of fine gold: 1st, the value of each centigram of gold in uncoined bar gold; 2nd, the value of each centigram of gold in new sovereigns; 3rd, the value of each centigram of gold in the sovereign just before ceasing to be lawfully in circulation. These values are in the ratio of the following sums of money, viz. 1st, £3 17*s.* 9*d.*, which is the price the Bank gives for $\frac{11}{12}$* oz. of gold in an ingot; 2nd, £3 17*s.* $10\frac{1}{2}$*d.*, which is the sum into which $\frac{11}{12}$ oz. of gold is coined; 3rd, £3 18*s.* $4\frac{1}{4}$*d.*, which is the sum into which $\frac{11}{12}$ oz. of gold would coin if the coins were made of the lightest weight which is legally current.

Until lately the Bank gave only £3 17*s.* 6*d.* for $\frac{11}{12}$ oz. of fine gold in light coins. Recently the price has been raised, and the Bank now gives £3 17*s.* 9*d.*, the same price as for bar gold. But there is no reason why the gold of light sovereigns should be treated as uncoined gold. It would be barely just to the holders of light coin that the State should purchase it at £3 17*s.* $10\frac{1}{2}$*d.*; and it would be consistent with justice for the State to give for it any sum between this and £3 18*s.* $4\frac{1}{4}$*d.* It is clearly for the interest of the community that as large a price as is practicable should be offered, because this will tend both to withdraw light gold from circulation and to diminish that range of fluctuation of purchasing-power to which money is subject even when no light gold is allowed to remain in circulation. It may be objected that there is a practical impediment to carrying the price beyond £3 17*s.* $10\frac{1}{2}$*d.*, as to do so tends to render the practice of sweating gold profitable; but the opportunity for this nefarious business would not be much greater than at present.

Another consideration offers itself which is deserving of attention, since it points out a way by which foreign transactions may be facilitated. It will be apparent from the foregoing discussion that one effect of the imposition of a mintage is to increase the average purchasing-power of each centigram of gold in a coin. Hence a centigram of gold in one of our coins has a somewhat less purchasing-power than a centigram of gold in the coinage of a country which makes a mint charge. Hence it would be a safe transaction for us to issue our own coins in exchange for such of the coins of foreign countries as may be brought to England in the course of trade, making the weights of fine gold they contain the basis of the exchange.

* In an ounce of the alloy called Standard gold there are $\frac{11}{12}$ oz. of fine gold.

Thus, according to a return made by the late Master of the Mint to the Royal Commission on International Coinage:—

Country.	Gold coin.		Centigrams of Fine Gold.	
Great Britain ..	Sovereign	contains	732	cents of fine gold.
	Half-sovereign	"	366	"
France, Belgium Switzerland, and Italy....	20-franc piece............	"	580	"
	10-franc piece............	"	290	"
	5-franc piece	"	145	"
United States of America	Eagle of ten dollars	"	1504	"
	Half-eagle	"	752	"
	Gold dollar............	"	150	"
Prussia	Friedrichs d'or of 1831	"	603	"
Zollverein	Krone	"	1000	"
	Half-krone	"	500	"
Austria	Ducat of 1860	"	344	"
Spain	Doubloon of 10 escudos....	"	754	"
Portugal	Crown of 10,000 reis......	"	1626	"
Brazil	Ten mille reis piece	"	821	"
British India ..	Gold mohur of 15 rupees ..	"	1062	"
Denmark......	Christian d'or............	"	594	"
Egypt	Fifty piastre piece	"	373	"
Greece........	Twenty drachmai piece....	"	519	"
Holland......	Double William..........	"	1211	"
	Double ducat	"	687	"
Malta	Doppia or pistole	"	707	"
Rome	Ten scudi piece	"	1560	"
Russia........	Half-Imperial of 5 roubles .	"	600	"
Sweden	Ducat	"	340	"
Turkey	Lira of 100 piastres	"	661	"

And if the Bank of England were required to exchange in London certain specified foreign gold coins (if within the limit of legal tender weight) for British money, estimating them all by such a table as the foregoing in cents of gold, a very important part of the advantages of an International coinage would be at once attained. And this great commercial convenience would be secured without our being in the least made dependent on the honesty of other nations; since the table of equivalents would be founded, not on the statements of foreign governments, but upon analyses and weighings made from time to time by our own Mint authorities. There would be no special difficulty in weighing the variety of coins which would be presented at the Bank; a very simple modification of the existing automatic machinery would accomplish this. Neither would there be any objectionable accumulation of foreign coins; the outgoings would go far to balance the incomings, and whatever surplus was in the Bank at any time would be estimated as part of the reserve which the Bank is bound to hold.

Another advantage would attend the carrying out of this proposal: it would contribute towards the establishment of the cent of fine gold as the unit of money of account; and this would be accompanied by all the advantages which group themselves round the fact that it is the Natural Unit.

On Immigration and Emigration, as affecting the increase of Population in England and Wales. By Thomas A. Welton.

The two censuses of birthplaces of 1851 and 1861, with the tables of registered births and deaths annually made public, and the available statistics of emigration, furnish the means of calculating with some degree of accuracy the net loss and gain in every single district by migration into and from it of natives of each county and of other countries.

Two ingredients in the calculation require to be estimated, viz. the numbers of

unregistered births, and those of deaths among residents not natives of the counties in which the respective districts are situate.

The number of births unregistered in 1851–60 has been estimated by the writer at 18,000 per annum, or nearly three to every 100 registered, on the grounds, (1) that by adopting such an estimate the population ascertained at the census of 1851, *plus* natural increase and computed immigration, but *minus* emigrants of English birth, gives a result which agrees closely with the population actually enumerated in 1861; and (2) that by applying such a correction there is deduced from the records of births and deaths in the years just preceding 1861, a number of children who should then have been enumerated at ages under five years, exceeding the number actually returned to as great an extent as could reasonably be expected, having regard to the probability that many children in their fifth year are erroneously returned as fully five years of age.

The annual ratio of deaths among persons not living in their native counties has been assumed to range between 15 and 20 per thousand persons, except in the case of the poorer class of Irish, who experience undoubtedly a much heavier rate of mortality.

Tables were appended to the paper, founded on these assumptions, showing not only the numbers of persons who in the ten years (1851–61) would appear to have removed from the Registration Division in which they were born to either of the other ten English divisions, but also the numbers of natives of other countries added to the population of each division, and (as a final arithmetical result of considerable interest) the numbers of natives of each of the eleven divisions respectively who must have been included amongst the emigrants to America and elsewhere.

In every case the numbers thus represented as having emigrated or immigrated are the balances resulting from setting arrivals against departures, and show the final outcome rather than the steps by which it was attained.

The net reduction of the natural increase of population in England and Wales occasioned by migrations in the ten years (1851–61) appears to have been about 267,222 males and 35,098 females, such loss arising from an emigration of natives of England and Wales amounting to 662,578, partly counterbalanced by an immigration of Scotch, Irish, foreigners, &c., amounting to 360,258; net loss, 302,320.

We may infer, from the numbers of immigrants actually enumerated, that the above figure, 360,258, was pretty equally divided between the sexes; hence we must conclude that the emigration was composed of about 457,000 males and 205,000 females.

There is good reason for the belief that a vast proportion of the immigrants on their arrival here were under twenty years of age. There are still stronger grounds for coming to the same conclusion with reference to 1,013,451 natives of England and Wales computed to have removed from their native division to one of the other ten divisions during the same period of time.

The imperfect returns* which we possess as to the numbers of English absent from home in 1861, show that the total, embracing soldiers, sailors, and travellers as well as residents abroad, was not far short of 1,350,000, viz. 900,000 males and 450,000 females.

This shows the number of persons of English birth in existence at that time to have been nearly such as would have resulted had the birth-rate in 1801–40 averaged as high as 37 per thousand inhabitants, and had it in subsequent years been such as is shown by the Registrar-General's returns, *plus* six per cent. for omissions in 1841–50, and three per cent. for omissions in 1851–60, the death-rate being assumed throughout to be the same as that shown in Dr. Farr's 'English Life Table No. 3.' But the surviving females are decidedly more numerous than the result of such a calculation would show. Consequently we are led to the conclusion that the life-table in question does not represent female longevity as compared with that of males in a sufficiently favourable light.

It also appears that the census of ages taken in 1841 must needs have been very inaccurate, and that, although the birth-rate in the first thirty years of the century may have exceeded 37 per thousand, it was in 1831–40 somewhat lower than that

* Returns showing the age, sex, and county of birth of persons of British origin absent from home on the Census day would be valuable.

figure. When we take into consideration the fact that the *corrected* birth-rates in subsequent years have been: in 1841–50 about $34\frac{1}{2}$, in 1851–60 about 35, and in 1861–70 about 36 per thousand, we are perhaps entitled to infer that an appreciable abatement in the rate was brought about through the operation of the new Poor Law.

Similar calculations with reference to the south-western counties, from whence the emigration has been largest, show that the birth-rate in that division in 1801–40 was probably near 35 per thousand, against 32 per thousand in the succeeding twenty years. The exodus from this division has been such that, for more than 700,000 natives aged 20–40 surviving in 1861, less than 500,000 persons were enumerated as resident, of course inclusive of strangers.

Other calculations show that the death-rate amongst *natives* of London is probably much higher than the observed mortality amongst *residents* would lead us to anticipate. It is desirable that returns should be obtained showing the place of nativity of the dying, the effect of which would be to disturb very materially the current ideas as to the significance of local death-rates.

Finally, it may be useful to state summarily the following results of this inquiry:—

1. Whilst the net loss by the emigration of natives of England and Wales amounted in the twenty years 1841–1861 to about 1,130,000 persons, the net gain by the immigration of persons born elsewhere amounted to about 740,000 persons, so that the average annual loss of population caused by migrations in those twenty years did not exceed 20,000 persons; and the loss by the same cause in 1861–70 has probably not exceeded 40,000 persons annually.

2. That more than 15 per cent. of the male natives of England and Wales aged 20–50 were absent in 1861 from their country.

3. That the census of England and Wales about to be taken will probably show the population to be nearly 22,500,000, and the excess of females to be nearly 700,000. The first of these figures is a quarter of a million larger, the second about 150,000 smaller, than the estimates published by the Registration Office would indicate.

On Decimal Money and a Common International Unit. *By* William Westgarth.

1st. Our arithmetical basis is decimal; that is, we count by tens. Must that therefore be the system in our money, weights, and measures, in all that concerns numbers, or are we free for any other counting? 2nd. The greatest diversity of national units, from the Spanish real of about $2\frac{1}{2}d.$ up to our own pound, shows that accident first and habit afterwards must have largely shared in the creation of such a family. Are some more suitable than others? and how does this appear? 3rd. Is the international arrangement really important?

Decimal Money.—Ten is not the best number, and probably never came into arithmetical use by design; eight and twelve, as more divisible, are better. Cannot we therefore alter our basis? The reply at this time of day is, that in whatever way ten-counting reached us, the world is now practically decimal, and will remain so. Then what is the effect of nonconformity to our basis? Try, for example, to convert 1,527,643 farthings into pounds, shillings, pence, and farthings; or to reduce 10,253 tons, 9 cwts., 3 qrs., 7 lbs., 8 oz., 6 dwts., 5 grains, into grains. With much time and trouble to all, a large proportion would for certain commit one or more mistakes in the process; and some might never get through at all, in the weights and measures at least, unless they could refresh their memories as to some part or other of the unsystematic medley. Such being our present nonconformity system, how are these puzzles dealt with decimally? Simply by pointing off the successive grades, or conversely, by erasing the decimal points. The two questions are thus instantaneously answered: £1,527 . 6 . 4 . 3, and 10,253,937,865 grains. The answer is not worked, it is simply read. Of course every one has not such long calculations as these to go through; but every one has something, more or less, of this kind daily and hourly in ordinary or business life, and wanting the decimal facility, all the multiplication and division becomes a superfluous toil. In short

the disadvantage in all that relates to numbers in quitting our arithmetical basis is manifest, continuous, and universal. That basis stands as the common figure, while money, weights, and measures are, as it were, so many varieties of its clothing. The latter must be adapted to the former and not left to other forms, even if in the abstract superior. As well might a tailor cut his suits from some model Apollo instead of his customer's own shape; nor would the customer feel much more comfortable even if convinced that Apollo's figure was the better of the two.

An International Unit.—The grand test of suitability must be general use. Thus tried, we find a middle region of fairly suitable units from a franc to a dollar. Lower values, as the real and the piastre, provoke the substitution of a higher unit when large amounts are dealt with. The Turks, for instance, whose piastre is only $1\frac{1}{4}$*d.*, tell up their revenues or debt by "purses," while a Frenchman is loyal to his franc even up to "milliards," and an American to his dollar in thousand millions. Our pound is of course the most convenient of all in such high-value regions, but it entirely fails elsewhere. The trading classes ignore it to a very great extent, as their shops and stalls everywhere testify, by such ticketed prices as 25*s.*, 50*s.*, 100*s.*, even 120*s.* upwards, instead of pounds. The vast mass of the poorer classes is still further from the pound. Probably more than half the money dealings of all classes together are for values under a pound. What does this mean, and what its disadvantage? No less than this, that of all this everlasting business of society the greater part is done in fractions instead of integers, which is much as though a traveller took one part of his journey in the usual forward motion and the other part backwards. The disadvantage is not felt in each individual step or even in a hundred, it is in the huge collective total of the journey. It is like the minute fraction of extra cost that seemed quite unworthy of attention, until we could realize that even the hundredth of a penny was important in millions of yards.

The franc, then, seems the lowest, as the dollar seems the highest, value that experience indicates as suitable by the test of general use. The other principal units are all under the dollar, our solitary and anomalous pound excepted. Perhaps the special well-being of America assists a rather high unit, thus confirming the view of its extreme position; but the scale of modern finance requires the highest value—the dollar rather than the franc. But, again, authority and habit cannot be ignored in this question, and the franc is backed by eighty millions of people comprised in the successful International League of 1865. The choice is perhaps restricted to one or other of these two units; either of them is greatly more suitable to us than the pound.

The Decimal Association has decided on a ten-franc unit. By the foregoing data this is proved obviously too high. The countless users of a franc unit will not, indeed cannot, rise to a ten-franc. The Association is a great authority; but another no less, the Paris International Conference of 1867, preferred the five-franc, that is, the dollar value. Our present moneys, the Association contend, could be readily adapted to the ten-franc unit: true, but so they could to the five-franc, and even more readily; for with the small alteration suggested last year by Mr. Lowe, the new coinage would be fifths of a pound (the new unit) and double pounds, or ten times the unit. The subsidiary silver and copper money would, with their allowable margin of seigniorage, be as easily dealt with. Here he would remark that, to carry out decimals in their integrity, there should be no intermediate coins; most countries, indeed all countries, decimal as well as non-decimal, are inveterate in this practice, which violates all decimal simplicity.

Of what importance is the International Arrangement?—Persons not undistinguished have answered in effect, "None;" little more than a convenience to excursionists. Such views seem incredible. There are certain great barriers to general intercourse—the foreign element, the different language, and the different moneys and measures. An international monetary and metric system would entirely sweep away the last, not perhaps the least, of these barriers.

Statistics on Tobacco, its Use and Abuses. By R. Wilkinson, *L.C.P.*

The main object of this paper was to show that the use of tobacco in its various forms tended to weaken the vital functions of the body, to interrupt the uniform ity

of their action, to rob life of much of its natural enjoyment, and to shorten the period of its duration.

In commenting on the diversity of opinion amongst the most eminent surgeons on this subject, the author argued that if pharmacy be really a science, its principles should not be less definite, nor their operation less uniform in their results than in ordinary sciences.

By careful compilers it is ascertained that in Great Britain there is an annual increase of consumption of tobacco of about 750,000 lbs. weight. In 1861, the quantity imported into this country was 34,828,441 lbs. The number of the male population at that time, aged fifteen years and upwards, was eight millions; and supposing only half of them to be smokers, it would give more than eight pounds to each smoker! Cigars and snuff do not come into this calculation.

With respect to the revenue from this source, the following particulars may be relied on, as they are copied from Government returns:—"In 1839, the duty was £3,587,663; 1847, £4,278,893; 1857, £5,272,470; 1859, £6,542,000."

These figures do not give the actual cost of smoking, snuffing, and chewing; we must add the whole paraphernalia of snuff-boxes and pipes of all descriptions, numberless and nameless, the construction of which has taxed the ingenuity of craftsmen; and by these additions we shall realize as much more as the duty, and thus produce the startling fact that £13,000,000 sterling of national wealth, and much industry that might have been better employed, are worse than wasted.

On Local Taxation. *By* O. Williams.

A report was presented to parliament last Session by a Committee of the House of Commons recommending that a moiety of the local taxation now paid by tenants should be transferred to owners of property. Mr. Williams maintains that this change would be so very far short of the requirements of the case as not to be worth the while to make it. He suggests that the area of payers should be very much enlarged, and maintains that the reasons for collecting the local taxes upon the same principle and by the same machinery as the income- and property-tax are very much the same. In his paper he shows that the poor-rate is a personal and not a property-tax; that all other local taxation is based upon the poor-rate assessments; and that, when the rent of property was originally fixed upon as the measure of the ability of each to pay according to his means, then the measure was much more just than under present circumstances, because the great bulk of income was derived from land, very little from foreign commerce. As immense profits are now made from trade, the writer urges that those profits should contribute, along with all kinds of house and other property, as for national taxation in the property-tax. He shows that, at present, owners pay all local taxes in large towns, where the great bulk of the population reside, upon property let at the net yearly rent of £13 and under; that if the recommendation of the Committee were carried out, owners would still have to pay all taxes on this very large class of property; and that the change practically would reach houses rented *above* £13 per annum net, the gross rental of which would range between £18 and £20 per annum. Shift half of the taxation from tenants to owners of such houses, and the owners will at once increase the rentals by the same amount. What matter to the tenants whether they pay to the tax-collector or the landlord? It is expanding commerce which necessitates wide, long, and good roads, brings into existence quite an army of police to protect its products, requires hundreds of thousands of hands to work it, and, surely, commerce should contribute directly towards all local taxation. After the payment of the interest upon the national debt, the great bulk of the remainder is expended upon the army and navy. And how are they employed? Mainly in protecting the lives of Her Majesty's subjects. In times of war those who have most property do not object to contribute most towards the expense of protecting it, and why should they not do so in times of peace. The army protects life and property, and so do the police force; the navy is similarly engaged on the seas; how are our river-police employed? the difference is not great. Then a glance should be taken at the paving, improvement, and lighting rates. All personalty should contribute towards them. Good wide roads are

greatly for the convenience of commerce; were roads narrow and in bad repair, wealth would not accumulate so very rapidly, nor would property or commercial products be as safe in banks and warehouses if streets were badly lighted. And the wear and tear of the roads, in the main arteries, is enormous by the grinding, crushing, and heavy loads drawn over them. Narrow streets have constantly to be widened by the growing demands of commerce, and it should be compelled to contribute towards the expense, which it would do through a property- and income-tax.

Then commerce should contribute towards the expense of an abundant water-supply, *i. e.* according to the value of products protected, as by insurance, not by a mere rate on a warehouse. A property- and income-tax would be an approximation.

Prevention is better than cure. Commerce should contribute towards the Library, Museum, and Education Rates, because property is safer in the midst of the educated. Mr. Williams shows that 1*d.* in the pound for the Library and Museum or poor-rate yields about £6300 per annum within the parliamentary borough of Liverpool; that 1*d.* in the pound for the property- and income-tax yields about £39,000 within the same area; and that a rate, on the principle of the property- and income-tax, of about $\frac{1}{2}$*d.* in the pouud would yield as much money as the present excessive rates of over 6*s.* in the pound.

He advocates that national and local taxes should be collected by the same collectors; that on the face of the tax-bills should be printed in two lines, National Taxes and Local Taxes; that the collectors should pay to the Government the national and to the local authorities the local taxes collected. And he suggests that the poor-rate authorities, the watch, education, sanitary, water, improvement, indeed that all committees should send into the mayors of the several boroughs the sums required by each for the next year; that they, respectively, should be required to send the amount required to the Chancellor of the Exchequer, who, again, would fix the rate to yield the amounts required and to be collected with, but separate from, the Government taxes. In this way the same local authorities as at present would have the expending of our taxation, maintaining the golden feature that those who pay shall expend their money through their representatives. Exceptional legislation is recommended, instead of a national bill, as the writer believes that it would be much easier to get a local bill than a general measure through the House.

MECHANICAL SCIENCE.

On a New Steam-power Meter. *By* Messrs. Ashton *and* Storey.

[Ordered to be printed *in extenso* among the Reports, see page 151.]

On the unprotected state of Liverpool. *By* Admiral Sir Edward Belcher, *K.C.B.*, *F.R.G.S.*

On a New Heat-Engine. *By* A. W. Bickerton, *F.C.S.*

The engine is intended to be worked by the expansion of crude nitrogen or common air, under the influence of heat. The air is heated in a serpentine system of tubes passing up and down inside a flue which surrounds the fireplace: the fire itself does not come in contact with the tubes; but as they entirely surround the fireplace, loss by radiation and conduction is prevented. The air to be heated is compressed and forced into the tubes at the end most distant from the fire, and as it travels forward it is gradually heated; so that the air to be heated is travelling towards, and the products of combustion away from the fire: in this way the heat is almost all abstracted from the products of combustion and given to the air, thus preventing the loss that usually occurs by the hot gases passing up the chimney. The air that has been expanded is allowed to pass out of the tubes from the end

nearest the fire, and to act upon a piston under full pressure through part of its stroke; it is then cut off and allowed to expand until the pressure is a little above that of the air, but it is still much hotter than the air; it then enters an air-chamber, and part of it is used for the blast of the fire, which is in a firebrick chamber without bars, the ashes fusing and flaming off as slag: the remainder of the spent air not used as a blast is mixed with the products of combustion immediately above the fire and before they enter the flue, thus diminishing the intensity of the heat and preventing its injuring the tubes, and also using up the heat of the spent air in helping to heat a fresh supply.

The complete cycle consists of the following steps:—Air is compressed, is forced into tubes, is then heated, then acts upon a piston, and a part of the spent air, which still retains considerable heat, is used as the blast and the rest in heating a fresh supply; thus the real work at our disposal is the difference between the compressing and working cylinders.

The above description applies to an engine where air is used; when nitrogen is used, the same gas is used over and over again, and slight modifications are necessary, but the general principle is the same.

By these means it is hoped that a considerable amount of the loss of heat that must accompany the use of steam may be avoided, especially that which passes up the chimney and that which passes away with the water that becomes heated in condensing the steam, an amount many times that which is converted into work in the steam-engine.

On a New System of Testing the Quality of the Malleable Metals and Alloys, with Experimental Illustrations. By Gustav Bischof, *Jun.*

Superior qualities of malleable metals and alloys are characterized by their being able permanently to extend in all directions by rolling or hammering without rupture, whilst inferior qualities break before reaching the maximum of extension which the former can endure. The cause of this is the difference of the cohesive power in different qualities of the same metal or alloy. From this it must be concluded that if different qualities of the same metal or alloy have been rolled in exactly the same manner, the better their quality the oftener they can, after rolling, be bent in reverse directions at a certain angle without breaking. Upon this principle my test is based.

The to-and-fro movements which, for instance, pure zinc, the best and the most inferior quality of commercial zinc hitherto tested, withstood without breaking, under the conditions presently described, were respectively in the ratio of 100, 54, and 19; for a good quality of steel, charcoal iron prepared by puddling, and ordinary bar iron the ratio was 100, 43, and 26; for different qualities of commercial copper between 100 and 19; for different qualities of commercial tin between 100 and 16, &c. It is obvious that once having such figures as standards, any other figure obtained in testing metals or alloys will indicate their quality in reference to the quality of the standard, the method being the more reliable, as properties which are essential for practical purposes form the criterion.

The accuracy and saving of time and labour through this test will be estimated from the fact, that, for instance, the deteriorating effect of as little as 1 part of tin upon 10 million parts of pure zinc, or of 1 part of cadmium upon 250,000 parts of pure zinc, can be detected with certainty in less than *one* hour, whilst such traces would probably escape the notice of a chemist if he spent a fortnight in analyzing.

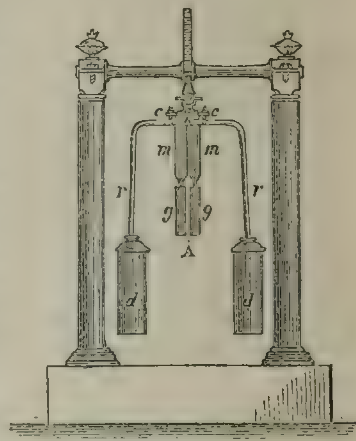
As the rolling of samples for comparative tests must always be effected under the same circumstances, the shape of the different samples must be alike before the rolling is commenced. Metals which do not, or not materially, alter in quality through fusion, are melted and poured into iron moulds of the required size, whilst metals which alter in quality through fusion are cut into bars of the required size. These bars are then, with or without annealing, according to the nature of the metal or alloy, rolled in a test rolling-mill until they have a standard weight.

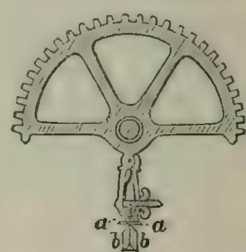
To the central screw of the rolling-mill which actuates the two screws which press upon the upper roller a dial-plate with pointer is attached, enabling one to

regulate the gradual pressure. The annealing, if required, is effected in tubes of fireclay heated externally.

As metals sometimes become jagged through rolling, strips 7 millims. wide are cut out of the middle of the samples after they have been rolled to nearly the required thickness, after which the rolling is continued until they have the standard weight.

The apparatus for bending the test-strips, which is termed a "metallometer," contains two essential points,—one or more vices *a* for fixing the test-strips, *m*, and a guide, *b*, through which the strips pass. The guide is capable of oscillating upon two axles, *c*, *c*, which rest in bearings fixed to the vice. The weights, *d*, *d*, which are connected with the guide by means of rods, *r*, *r*, always keep the guide in a vertical position when an oscillating motion to the right or left is imparted to the vice. Thus the guide forms an angle with the vice at each to-and-fro movement, and the test-strips, which are passed through the guide and fixed by the vices, are also bent alternatively to the right and left, by preference to an angle of $67\frac{1}{2}$ degrees to the vertical line, until they break, whereupon the parts severed are caused to fall off by means of the small weights (*g*, *g*) attached to them. The motive power (by preference clock-work) which actuates the metallometer has a dial-plate with pointer which marks the number of to-and-fro movements which the sample withstood before breaking off.





As no metal or alloy is quite homogeneous, it is necessary to make a series of tests in order to arrive at an average result.

The metallometer which was exhibited had five vices, each for two test-strips. Its working was illustrated by testing copper. The test-mark (or figure indicated on the dial of the clock-work) of a sample of commercial copper, which had been tested previously, was stated to be 51. A corresponding sample of the same copper, which was tested in the presence of the Meeting, gave on the average 52·5, showing that the *same* quality is indicated by the *same*, or at least closely the same, test-mark.

Next, a sample of the same copper as above, which, however, had been heated a short time in a current of hydrogen, was tested. It is evident that the latter treatment must impair the toughness. The test-mark obtained in this experiment, being only about $\frac{1}{5}$ of that obtained in the former, proved how extremely sensitive the metallometric indications are.

Other samples of brass, steel, iron, tin, zinc, and lead, which had been prepared, could not be tested for want of time.

On Bowater's *Patent for Manufacturing Railway-axles.* *By* Alfred Bowater.

A machine for manufacturing iron or steel bars at one operation into axles. These axles will be of a superior quality, more uniform in size, and cheaper and more quickly produced than those generally in use.

Under the present system of manufacturing axles, a bar or billet of iron or steel is first heated at one end and then shaped under the forge-hammer, and afterwards similarly heated and shaped at the other end, an operation of some time.

Under the above patent a bar or billet of the desired length and quality, made a little larger in diameter than the thickest portion of the finished axle, is heated

bodily, and placed in the machine, which reduces it at one operation to the required size and shape. The rolls of the machine are geared together so as to rotate in the same direction; the iron is placed between the working rolls, which are brought to bear upon the bar by powerful screws gradually pressing the rolls nearer together and reducing the bar to the required dimensions. The part of the rolls which form the tournals press upon the bar, reducing its diameter at that point, afterward bearing upon the middle of the bar, and by degrees along its whole length. As the bar becomes reduced in diameter it becomes extended in length 14 to 18 inches; to allow for this elongation, those parts of the rolls which form the tournals are arranged to slide laterally with the axle, while the rolls are screwed closer together until the finished axle is produced, and which, by the greater uniformity of the rolling pressure, gives the direction to the fibre best calculated to increase the strength of the axle.

Hydraulic Machinery for Steering, Stopping, and Working Heavy Steam-engines discharging Cargo. By Andrew Betts Brown.

The chief feature of novelty in the invention, as set forth in this paper, is in an apparatus called a "steam-accumulator," by which a reservoir of water at a pressure of 1000 lbs. per square inch and upwards is obtained on board ship. Having this pressure, a steering-gear of light construction and great power is made use of possessing certain relief valves, or other expedients by which perfect elasticity in the rudder may be obtained.

In a similar manner, by the use of hydraulic cylinders and rams, the same pumping-machinery and "steam-accumulator" which works the rudder at sea is made available in port for the discharge of a ship's cargo, as well as, on entering a port, to start, stop, and reverse heavy marine engines.

On Appliances for the production of Heavy Forging. By Lieut.-Colonel Clay.

On the Purification of Public Thoroughfares. By W. J. Cooper.

[For an abstract of this paper see Section B, page 53.]

On the Efficiency of Furnaces and Mechanical Firing. By George F. Deacon, *C.E.*

In opening this subject, the author referred to one of the very numerous experiments of the late Mr. C. Wye Williams, in which air was admitted to the volatile products of combustion of the carbon through holes in an arched plate, dividing the fuel from end to end of the furnace. Mr. Williams firmly believed that such a system was capable of producing perfect combustion, and he strenuously opposed the idea that any advantage was to be gained by making use of air for the combustion of the inflammable gases which had been raised in temperature by heat abstracted from the furnace in which they were produced. The well-known experiments of Professor Tyndall and Dr. Frankland, by which it was clearly shown that, owing to the greater inability of the atoms of rarefied air, the energy of combustion was within wide limits independent of the density of the air, went far to overturn the arguments with which Mr. Williams upheld his opinions.

Arrangements similar in form to the perforated arched plate had been tried by the author; but in a series of careful experiments on a large scale only those which had included means for heating the inflowing air had been found efficient in producing perfect combustion of the gases. Transverse arched bars 7 or 8 inches high, presenting to the rising air extensive heating-surfaces, had been substituted for the bent plate, the heat for raising the temperature of the air having been obtained, both by radiation and conduction, from the incandescent fuel.

The results of the author's experiments may be summed up as follows:—

1st. The admission of cold air above the fuel in quantities sufficient for the complete combustion of the inflammable gases is in most cases attended with loss of efficiency, even if such admission takes place in jets over the whole surface of the fuel. Smoke, however, is considerably reduced.

2nd. By the motion of the air over heated surfaces, and its consequent rarefaction and increase of velocity when issuing from orifices in the arched bars, much more perfect chemical union with the inflammable gases is insured; the flame is rendered less luminous, but its temperature is increased; the radiation of heat is diminished, and the furnace door becomes less hot. Smoke is almost entirely prevented, and a higher rate of efficiency is attained.

The author then proceeded to explain the great difficulties in the way of working furnaces economically by hand firing, and stated that Stanley's patent machine for supplying coal to furnaces by means of horizontal fans, well known twenty or thirty years ago, but now limited in its application to a few manufactories in Yorkshire, was probably the first apparatus for mechanical firing ever made. It was difficult to understand why this machine, which with all its imperfections had been used in almost every mill in Lancashire until the new system of boilers was introduced, should be found in Leeds still at work in the crude form in which the original inventor had left it. This being the only feeder which rained down the fuel evenly on every part of the furnace, involved a principle which was clearly correct; but to render it efficient it required provision to be made for the combustion of the gases thus uniformly set free. Such desideratum the author stated had been supplied by combining with it the central arched bars. This arrangement, and the improvements made upon the machine itself, had given the following satisfactory results. The entire apparatus, consisting of a self-feeding furnace emitting no smoke, comprised considerably fewer working parts than any of the old machines. It had now assumed a form capable of being manufactured at less than one-half the cost of those mechanical stokers in which the fuel had a progressive motion towards the back, and the imperfections of which were principally attributable to the difficulty of regulating the admission of air through the bars at the back of the furnace.

The efficiency of the combined apparatus above that of the arched bar furnace when fired by hand had been found by careful evaporative trials to be 9·696 per cent.

In conclusion the author stated that a feeder and furnace constructed on the principles advocated had been in successful operation day and night for nearly five months at the works of Messrs. Earles and King in Liverpool.

Some Remarks on the extent to which existing Works and Practice militate against the Profitable Utilization of Sewage. By John Bailey Denton, *M. Inst. C.E., F.G.S.*

This paper points out that although the sewers of towns were not designedly made leaky, they were not constructed of a material and in a manner to secure their being water-tight, while in many cases the subsoil-water was intentionally admitted. The original "General Board of Health" recommended that all sewers should be water-tight, and that there should be a separate system of pervious channels for the removal of subsoil-water, which, it was stated, could be readily made to discharge their contents into the sewers when required for flushing or dilution. The consideration of these very important points is of little avail in those numerous towns where a complete system of sewerage works have been carried out, as the difficulty and expense of altering them would negative any such proposition; but it will be of great value in influencing the character of works yet to be performed in small towns and villages where no systematic provision exists, and in places where an alteration of existing sewers is practicable at a moderate cost.

To show to what extent existing leaky sewers, admitting subsoil-water, will allow of the passage of sewage out of them into the surrounding soil is most difficult; but the fact must commend itself to all, that, under certain conditions, a

fluid existing inside a sewer may pass as rapidly out of it into the surrounding ground as the subsoil-water may pass from that ground into the sewer. This effect will be conceded when the height and pressure of the one exceeds the height and pressure of the other. Though the difficulty of ascertaining the quantity of sewage which escapes is great, and the facts will only become apparent when disease becomes localized in the neighbourhood of leaky sewers, there exists no difficulty in determining the extent to which the influx of subsoil-water takes place. The greatest increase from the infiltration of subsoil-water known to the writer is at Tring and Hertford. In the first case, although the sewers are only connected with 30 houses, and the whole influx of sewage does not amount to 1000 galls. per diem, the dry-weather discharge from the main sewer amounts to upwards of 1,000,000 galls. per diem. The effect of this abstraction of water from the subsoil has been to lower all the springs in the neighbourhood, and to lay nearly dry the head of the silk-mill in the town, from whence the Grand Junction Canal Company obtained a supply of water at a summit level. In the case of Hertford, the discharge from the sewers is more than nine times the water-supply. At Blackpool, for instance, with a standing population of 7000, the water-supply is about a quarter of a million gallons daily, and the discharge from the sewers about 1,000,000 gallons. There is, therefore, an infiltration of water from some source of three-quarters of a million gallons, and no effort is made to keep the sewage on the flow when the tides rise above the sewers. In the town of Dover, with a standing population of about 25,000, where the water-supply is upwards of 1,000,000 galls. daily, the ordinary dry-weather discharge from the sewers amounts to nearly 3,500,000. Here, in order to keep the sewage "on the flow," pumping is resorted to for two hours before and two hours after each high tide; and it is possible that by such means the escape of sewage is in some measure reduced by avoiding the extreme pressure of maximum accumulation. Under any circumstances it will be observed that the expense of pumping is increased by the influx of subterranean water in the proportion of 1 to $3\frac{1}{2}$, and, as a natural consequence, that £350 is spent when about £100 would suffice if the sewage alone was dealt with. If the returns of mortality in these places could be brought to bear, it would doubtless be found that certain epidemics are localized in the low parts of the town, while other diseases prevail in the higher parts, caused by the pent-up gases generated by detention finding their way upwards. This periodical condition of surcharged sewers is not confined to seaboard towns. In cases where the sewage is lifted, the sewer authorities may allow the sewage to accumulate in the sewers in order to avoid the expense of pumping at night, when precisely the same effect is produced as in seaboard towns under tidal influence. In many of the Lancashire towns, such as Bolton, Liverpool, Oldham, and Warrington, the aggregate daily excess due to subsoil-water in these four towns alone reaches, I have reason to believe, something between 20 and 25 millions of gallons, which, if lifted 100 feet, would cost, at 20*s*. per million gallons, upwards of £8000 a year. At Cardiff, in South Wales, the increase is 1,500,000, without any advantage in the way of flushing and cleansing (which, it has been stated, always accompanies the influx of water), for there the inflowing subsoil-water brings in with it a share of the sand, which deposits itself in the sewers, and is likely to become an increasing source of impediment and difficulty. In many instances of both seaboard and inland towns the sewage has been more than doubled; and wherever it becomes necessary, on the ground of health and economy, to lift the sewage by mechanical power (as we may safely assume will be the case in all towns, without exception, where the sewers have not a free flow), the difficulty and cost of dealing with such an increased quantity will become proportionately greater. These observations are made with a full recognition of the difficulty, almost amounting to an impossibility, of making ordinary sewers completely water-tight, and of the truth that water finding its way into sewers sometimes acts beneficially in flushing them, and that at certain seasons the dilution of sewage applied to irrigation is advantageous. It is to the evil of indiscriminately admitting a largely disproportionate quantity of water, without any power to regulate the time and extent of dilution, to which attention should be called with a view to determine future proceedings.

Turning from sewage works to the utilization of sewage by irrigation, which the Rivers Pollution Commissioners have recommended as the only plan of dealing with the sewage difficulty at present known, a very strong opinion has prevailed, and has been acted upon up to the present time, that it is only necessary to run the sewage over a surface of land covered with growing vegetation to extract from it all that is fertilizing, and to render the effluent liquid perfectly harmless. It has not been considered necessary that sewage should pass through, as well as over, the soil. The Rivers Pollution Commissioners themselves appear to have considered filtration, both downward and upward, separately from irrigation, and to have reported upon each as distinct operations; for, after advising a trial of intermittent downward filtration on a large scale, they add that in all practicable cases they would strongly recommend "the adoption of irrigation in preference to filtration," evidently considering that irrigation can be properly adopted without filtration. It is to this very important recommendation, as one likely to mislead if not at once set right, that attention is called; for by those who have made agriculture a study, and have traced the effects of irrigation in England, Lombardy, and elsewhere, it is considered that no irrigation is perfect unless it be accompanied by filtration, and that if purification of the sewage is to accompany its profitable application to land, it is absolutely necessary that no liquid whatever should pass off the surface, but that the whole should go through the soil as well as over it. In no case where the sewage has uniformly filtered through a sufficient depth of soil has failure occurred. In one case (Walton Convalescent Hospital) within my own practice, the effluent water from a small area of land receiving the sewage of upwards of 300 people, having been subjected last year to a properly devised mode of natural filtration, in conjunction with irrigation, was analyzed by Dr. Odling, and declared to be "unexceptionable potable water." In this case the soil is free and porous, though it was excessively wet before it was drained. The sewage having satisfied the growing vegetation is absorbed by the soil, and passing downwards by filtration (naturally incident to under-drainage) is mixed with a constant and copious flow of subsoil-water, the level of which is maintained by the under drains. At Briton's Farm, near Romford, Mr. William Hope, V.C., has dealt with a somewhat different description of land, though of similar porosity. He has had the whole drained at a minimum depth of 5 feet, and the effluent water from the under drains, though not equal in purity to that just referred to, shows very distinctly the superiority of irrigation in connexion with filtration over irrigation simply. At Briton's (as at Walton) not a drop of water passes off the land.

Though the instances are few in which irrigation and natural filtration have been associated in executed works of sewage utilization, they are sufficient to support the conclusion that no irrigation should be adopted in which filtration does not form a part of the system. At Penrith, Carlisle, and Bedford, the whole of the sewage is absorbed at the surface and discharged in different ways from the subsoil, and the amount of nitrogen and ammonia existing in the effluent water is stated, in the report of the Rivers Pollution Commission, to be as follows:—

IN PARTS OF 100,000.

	Organic nitrogen.	Ammonia.
Penrith	·108	·001
Carlisle	·204	·025
Bedford	·034	·095

In the first two cases there appears to be no nitrogen as nitrates and nitrites, but in the last they are represented as ·505. With complete pulverization of soil sewage farms may be established with security in any part of the country, inasmuch as natural downward filtration, which is only another term for subsoil-drainage, is not only a sure means of purifying liquid sewage, as shown by the Rivers Pollution Commissioners, but it is equally sure to free the atmosphere of those noxious gases which several high medical authorities have feared may be evolved from the surfaces irrigated with sewage matter.

On certain Economical Improvements in obtaining Motive Power. *By* RICHARD EATON.

The paper recalled to mind the description given at Exeter of the Warsop aero-steam-engine, and the promise to communicate results of further trials of the system, which have now been made in several places. A well-known Lancashire firm had built one of the engines for use in their own works, and had found a fuel-consumption of 60 cwt. per week with the air, as against 86 cwt. per week when the air was shut off. Without the air-injection an average pressure of $33\frac{1}{2}$ lbs. was shown, whilst with it a pressure of 47 lbs. was kept up. An engine of the best construction, built for himself in London, showed, with the air-injection, a gain of $24\frac{1}{2}$ per cent. in work done at ordinary speed, and of $33\frac{1}{2}$ per cent. at a higher speed. The consumption of ordinary Welsh engine-coal was, with steam only, 5·88 lbs. per actual horse-power per hour; with steam and air 4·72 lbs., or a gain of 1·16 lb. per horse-power per hour—a very valuable economy. Experiments with locomotive-engines were referred to, and experiments with condensing-engines, made at the suggestion of Professor Rankine, showed the vacuum to be very slightly interfered with, contrary to expectation, and that the extra steam generated counterbalanced the loss of vacuum, while the fuel-consumption was alike under the two principles. The inventor has improved and simplified the condensing-engine proper to an extent that will prove an invaluable boon to all owners of steam-vessels.

Repeated and varied experiments proved that the air-injection prevented scaling in stationary and locomotive-boilers, and saline incrustation in marine boilers, and thus added to their durability and diminished the risk of explosion, whilst priming was prevented in all cases.

On the Gauge for Railways of the Future. *By* R. F. FAIRLIE, *C.E.*

The object of this paper was to advance a new argument in favour of the use of a narrow gauge in the construction of railways, founded upon a comparison of the amount of weight hauled for the same amount of paying traffic over a railway of 3-ft. gauge and a railway of the English "narrow" or 4-ft. $8\frac{1}{2}$-in. gauge. Although maintaining that the principle of his argument applied to passenger-traffic, and that the cost of working a railway, or, in other words, the proportion of non-paying to paying weight (as far as this is independant of management), is increased exactly in proportion as the rails are further apart, because a ton of materials disposed upon a narrow gauge is stronger as regards its carrying-power than the same weight when spread over a wider basis, the author on the present occasion went into detail only with regard to the conveyance of goods; and he selected the London and North-Western Railway as his illustration of the effects of the 4-ft. $8\frac{1}{2}$-in. gauge, on the ground that its management is so good that the defects in its working must be wholly traceable to its construction. He undertook to show that this line, if made on a 3-ft. gauge, would accommodate the whole of its present goods-traffic as well as at present, and would do so at half the present cost with half the present tonnage and motive power, and with half the present wear and tear of rails, so that the expense now being incurred for the construction of a third line would be rendered unnecessary. Assuming that the present goods-traffic, independently of minerals, amounts to ten millions of tons per annum, and that the non-paying weight of trucks by which these goods are hauled amounts to the low estimate of 40 millions of tons more (70 millions being nearer the truth), there results a total gross weight hauled by the locomotives of 50 millions of tons, at an average speed of 25 miles an hour. The earnings for the goods-traffic on this line are 6*s.* 3*d.* per train mile, which, at an average rate all round of $1\frac{1}{2}d.$ per ton per mile, would give about 50 tons as the paying weight, and 250 tons as the gross weight hauled per train mile; dividing this 250 tons into the 50 millions gives 200,000 trains, which, being divided over the 313 working days of a year, gives 639 merchandize trains over all parts of the North-Western Railway in the 24 hours. The Company's balance-sheet shows that each net ton produces about 4*s.* 8*d.*, which, at $1\frac{1}{2}d.$ per ton per mile, makes the average distance by each ton

to be about 38 miles; so that as each ton of the total weight hauled runs 38 miles, and the entire length of line worked is 1432 miles, it follows that there must be on an average 37 merchandize trains distributed over the total length. This number, divided into the total number of trains per day of 24 hours, gives an average of over 17 trains per day running on each mile of the line. Having reached this conclusion, it becomes possible to see how it would affect the question if the gauge of the line were 3 ft. instead of 4 ft. 8½ in. In the first place, the same or a greater speed could be maintained, say, up to 35 or 40 miles an hour. On the 4-ft. 8½-in. gauge the proportion of paying to non-paying has been taken at 1 to 4, although it has proved largely in excess of this. The waggons employed average 4 tons in weight, so that on this reckoning each waggon carries 1 ton for every mile it runs. The waggons for a line of 3-ft. gauge weigh each 1 ton, and carry a maximum load of 3 tons. Supposing that the same number of waggons and trains were run on the narrow gauge as on the broad, it follows that the average one ton of merchandize now taken could easily be taken in a waggon weighing 1 ton instead of 4 tons, and that the gross load passing over the line for one year would be only 25,000,000 of tons instead of 50,000,000, while the same amount of paying weight would be carried in either case; that is, the small waggons, which are capable of carrying three times the weight of goods now actually carried in a 4-ton waggon, would only have to carry one-third of that quantity, and would produce the same paying load as the heavier waggons; and as the haulage is precisely the same whether the tons hauled consist of paying or non-paying load, it follows that this expense would be reduced to two-fifths of what it now is. If the same number of trains were to run per day, the weight of each would be reduced from 250 tons to 102 tons; or if the same gross weight of train was employed, the number of trains per day would be reduced from 639 to 250. If there should be sufficient traffic to load the narrow-gauge waggons in such a way as to require the same number and weight of trains that are now worked, the result would be that, without increasing by one penny the cost of haulage and the permanent way expenses, the 3-ft. gauge would carry a paying of 25 millions of tons as against the 10 millions now carried. Here, then, we have established the fact that, so far as capacity goes, the narrow gauge is superior to the broad one; the former can produce 25 millions net out of a gross tonnage of 50 millions, while the latter, to produce the same result, if continued to be worked as it now is, would require that 125 million tons should be hauled, and that at an increased cost in the same proportion of 125 millions to 50 millions. The rest of the paper was devoted to an application of these figures to the question of the best gauge for Indian and Colonial railways, and to the argument that such railways might be made cheaply and efficiently on a 3-ft. gauge, so as to charge a reasonable tariff and to afford a satisfactory return.

On the Application of the Centre-Rail System to a Railway in Brazil and to other Mountain Lines; also on the Advantages of Narrow-Gauge Railways. By J. B. Fell, *C.E.*

The author said that since the opening of the Mont-Cenis Railway in June 1868, other mountain lines on the centre-rail system have been under consideration in different parts of the world. One of these lines now being constructed is in Brazil; it commences at the terminus of the Canta-Gallo Railway, crosses the Serra at an elevation of 3000 feet above the Canta-Gallo line, and terminates at the town of Novo Friburgo, a distance of 20 miles. In some of its principal features this railway resembles the summit line of the Mont-Cenis, the gradients for the passage of the Serra, over a distance of ten miles, being principally from 1 in 20 to 1 in 12, and the curves by which the line winds round the spurs or counter forts of the mountain being, for a considerable portion of it, from 40 to 100 metres radius. The narrow gauge of 1·10 metre has also been adopted. In other features, however, there is an important difference between these two centre-rail lines. The concession for the Mont-Cenis was but temporary, terminating at the completion of the great tunnel, and the railway is laid on the existing public road, whereas

the Canta-Gallo line will be permanent, and the works will be so constructed as to be specially adapted to its requirements. It will not have to contend with the difficulties of an Alpine climate, and, profiting by the experience of two years' working on the Mont-Cenis, it will have the advantage of important improvements which have been made in the engines, carriages, and permanent way during that period. Consequently the Canta-Gallo and other similar lines now being or about to be commenced have the interest of marking an important development of the capabilities and advantages of the centre-rail system as applied to the construction and working of mountain railways. It may be useful here to record what has already been accomplished in the task of carrying railways over mountain-passes hitherto inaccessible to the locomotive, and of giving it the power of safely carrying trains of passengers and goods upon gradients and curves which would previously have been considered most perilous, and, indeed, impracticable. The Mont-Cenis Railway has now been open for traffic two years and three months, and during that period the trains have run a distance of more than 200,000 miles, have carried between France and Italy over 100,000 passengers without injury to any one of them, and has effected the transport of a considerable quantity of merchandize. Since the month of September last it has carried the accelerated Indian mail, and by the service thus established the delivery of the Indian mail in London *viâ* Marseilles has been anticipated by the Brindisi and Mont-Cenis route by about thirty hours. The ordinary mails between France and Italy have been carried by the Mont-Cenis Railway since its opening, and one night of travelling has been cut off the journey between Paris and Turin. Although the Mont-Cenis Railway cannot be taken as a type of the best or most approved application of the centre-rail system, it has had the effect of proving its mechanical practicability and safety when put to the most crucial test to which any new principle could be submitted. There have been mechanical defects in the construction of the engines which have added unnecessarily to the cost of traction, and these defects can and will be removed in the engines about to be built for the Brazilian and for future centre-rail lines. The cost of traction, as might be expected under the circumstances, has hitherto been high (about 3 f. per train kilometre); but there can be no doubt that with improved engines and good management the cost of traction may be reduced to 1 f. 50 c. per train kilometre. The Semmering incline in Austria furnishes an example of the economy that may be effected by improved machinery and management, the cost of locomotive-power having been reduced from 2·85 f. in 1860 to 2·15 f. in 1863, 1·70 f. in 1865, and 1·49 f. in 1866. In the four new engines last built for the Mont-Cenis a considerable saving has been made in the cost of repairs by using four cylinders in place of two. By this arrangement the inside and outside mechanisms are disconnected, and any contention between the two is avoided. The adhesion, however, is not equal to the two-cylinder engines, and the power is transmitted from the inside cylinders to the vertical axles by means of a train of toothed wheels. In the new engines for the Canta-Gallo line it is proposed to dispense with the toothed wheels and substitute for them a system of direct driving by connecting-rods. The power of adhesion will also be considerably increased. These new engines will have the advantage of being able to run at a speed of from 20 to 30 miles an hour upon the ordinary gradients of the line, and of taking their loads up the mountain-section at a diminished speed of from eight to ten miles an hour. In an economic point of view the result of the application of the centre-rail system to the Canta-Gallo Railway will be as follows. The cost of construction, assuming it to be, as estimated, about £300,000, would be at least doubled if made on gradients upon which ordinary engines could work. In this case the costs of traction and maintenance for a centre-rail line will not be greater than for a line with ordinary gradients passing over the same country. The clear saving, therefore, effected by employing the centre-rail system is at least £300,000, and the construction of a valuable line of railway has been rendered possible, which would otherwise have been commercially and financially impracticable. A somewhat similar line of railway is under consideration by the Indian Government, from the port of Karwar to Hooble, in the Southern Mahratta country, both by way of the Arbyle and the Kyga Ghats. The distance is 90 miles, and it is proposed to employ

the centre rail for a length of about 10 miles upon gradients of 1 in 20 for the passage of the Ghat, by which a saving would be effected of about £500,000. The cost at the present time of the transport of cotton and other produce over the 90 miles is stated to be £235,000 per annum, and there is, in addition, the disadvantage of not being able to convey the whole crop to the port of shipment before the rainy season sets in; a large portion of it has consequently to be housed and kept until that is over. Negotiations are going on with the Government local authorities and people interested for the construction of centre-rail lines in Italy from the Adriatic to Macerata and crossing the Apennines to Foligno from Florence to Faenza, and for three branch railways in the Neapolitan States; in France, from Chambery to St. André du Gaz and Lyons direct, crossing the Col de l'Epine; in Switzerland, for the passage of the Simplon; and in Spain, for lines from Leon to Corunna and Gion. The concession for the Mont-Cenis Railway expires on the opening of the tunnel line; and when that period arrives, it has been proposed to remove it to one of the neighbouring mountain-passes, where it would have a permanent life. At the time the concessions were granted it was considered that the line would be worked for ten, or at least seven years; the progress of the great tunnel has, however, been so much accelerated, that it is stated the tunnel line may possibly be opened for traffic by the end of 1871. In that case, and taking into account the difficulties of all kinds with which the enterprise has had to contend, the Mont-Cenis Railway can only be regarded as an experimental line, and the pioneer of a system destined to confer the benefits of cheap and safe communication between many countries separated by mountain-ranges hitherto impassable by railways and locomotive-engines, and the promoters must look to the future for the reward of their labours and the anxieties of the past. Drawings were exhibited of a new system of narrow-gauge or suspension railways, an example of which has recently been constructed as a branch line for carrying iron-ore from the Park-house Mines to the Furness Railway in North Lancashire. The gauge of this line is eight inches, and the length about one mile. It is carried at various elevations, from 3 to 20 feet, over an undulating country, passing over the fences, roads, and watercourses without requiring the construction of earthworks or masonry. The structure consists of a double beam of wood, supported at intervals on a single row of pillars. The narrow gauge is practically made equivalent to a broader one by the steadying-power of guide-rails fixed on the sides of the beam and below the carrying-rails. The bodies of the waggons are suspended from the axles, and by this means the centre of gravity is brought low. They are also furnished with horizontal wheels, which run upon the guide-bars, and thus maintain the equilibrium of the carriages, and render it almost impossible for them to leave the rails. The Park-house line will have a traffic of 50,000 tons per annum. The cost has been £1000 per mile without stations or rolling stock. It was worked by a stationary engine and endless wire rope. The saving effected in the cost of transport will be at least 6*d*. per ton upon the distance of one mile. In Switzerland, application has been made to the Government of the Canton Vaud for a passenger line on this principle, from the town of Lausanne to the Lake of Geneva. Plans have also been laid before the War Office for accelerating military transport in foreign countries, and before the Governor-General of India for the construction of cheap branches from the trunk lines in that country. The gauge of these railways may be from 6 to 18 inches. They may be made of wood or iron, or of the two combined, and may be worked by either stationary engines or by locomotives of a form specially designed for the purpose. They have the advantages of being economical in both construction and working; they occupy but little land and cause no severance; they may be erected with great rapidity, and, being portable, may be removed when no longer required and reerected in another locality. Before the war commenced an offer was made to the French Government to construct one of these portable railways to supply their army with from 1000 to 3000 tons of ammunition and provisions per day. The work would have been undertaken by a gentleman in Paris, who, with a force of 2500 men, would have constructed from four to five miles of railway per day, following the advance of the army into Germany. The result has, however, shown how little such a provision was needed.

On the North-China and Japan Submarine Cables. By WILLIAM HOOPER.

On the History of the Shell that won the Battle of Sedan. By W. HOPE, *V.C.*

On Frictional Screw Motions. By G. LAUDER, *C.E.*

On Hammering and Stone-dressing Machinery. By J. H. LLOYD, *M.D.*

On the Defence of Liverpool by Floating Forts. By SAMUEL J. MACKIE, *C.E.*

Liverpool, the second commercial port in Great Britain, is at this time totally undefended, and cannot be protected by shore-forts. The proposed new forts and the proposed fleet of small unarmed one-gun boats might defend, but could not protect, either the town or the docks from injury by an enemy's fire. There is only one way of effectually securing for the ports and shipping of the Mersey immunity from bombardment, namely, the closing of the two great shipways, the Queen's and the Horse channels, and thus keeping the hostile guns beyond their range, the carrying, in fact, the sea-fight ten or twelve miles away from the mouth of the river. Ships and shore-forts cannot accomplish this; and it can be effected only by floating forts of proper and suitable construction. One broadside-ship is at best only good against two others; one turret-ship could only fight one other. The defences of Liverpool must be prepared to meet a fleet. Any number of unarmoured vessels could not effect this vital end. Unprotected vessels carrying single guns would be certain, sooner or later, to be hit and sunk. Our heaviest guns, the 600-pounders, would just pierce the battery-armour of the 'Hercules,' but would not penetrate her water-line belt at 150 yards. Our first-class iron-clads would be perfectly safe at two miles; but any one of the projectiles from their armaments would sink an unarmoured gun-boat at five miles, indeed wherever it could hit her. The unarmoured vessel, however, could not keep out of harm's way: she must come within 3000 yards to attack any iron-clad, for her guns must punch the armour of her adversary to do any injury at all; and there would be no chance of sinking the iron-clad until her belt was ruptured. It is not right to assume that gun-boats would not be hit, small and active though they be. In practice made at Shoeburyness in 1868 the bull's-eye of a target painted to represent the port-hole of a ship had three shots put into it by a 250-pounder gun out of nine rounds, all the rest being within 2 feet of the mark. The running-target, 6 feet by 6 feet, is repeatedly hit by the officers and men of the School of Gunnery. The smallest vessels being then so much larger than these objects, there are no substantial grounds for the idea that they should be able to attack with impunity iron-clad men-of-war.

What is really wanted for the protection of Liverpool is at least two impregnable iron floating forts, capable, even if by any disaster or by design they should be sunk, of fighting some of their guns above water. Such forts can be made, and the principle of construction advocated has already passed the bounds of mere hypothesis. Any fort, however strongly built, must get injured by the terrific blows of modern projectiles; and as water finds access only too readily through cracks and fissures, it is right to provide a resource against the last emergency. Another consideration is that the battery afloat might be in danger of being overpowered by ramming, which could be avoided by voluntary submergence on a shoal or on the sea-bed in sufficiently shallow water. Rifled guns (in other words, weapons of precision) require, above all things, a perfectly steady and stable platform. Accurate aim is the primary consideration in their use. Ships are adapted for sailing, not for gun-carriages. The proper lively motion of a ship is absolutely antagonistic to steadiness of platform. Masts are not required in a floating fort; steam-power applied as hydraulic propulsion can give all the propulsion required.

The four-rayed forts proposed by Mr. Moody, an able and most experienced captain in the merchant-service, have perfectly all the qualities required. In prin-

ciple they are double pendulums, the swing of which is absolute in two directions at right angles to each other. The centre of gravity is vertically over or coincident with the centre of the mass. The oscillation is reduced to a minimum; the draught of water is light. In turret-ships the longitudinal oscillation limits the sites of the turrets to two points at such distances from the middle of the vessel as within which the motion is not too extensive to permit of the training of the guns. In the four-rayed forts guns can be mounted all round the circumference of a circle drawn continuously at the same distance from the central point of least or no motion. Thus the practical arming of the floating fort, as compared to that of a ship, could be as 8 to 4. The fort is flat-bottomed and buoyant throughout; stability and steadiness are essential qualities. If sunk it would not heel over, and when grounded it would remain upright, and in the shoal water of Liverpool Bay would still keep its port-cills above water, so that the guns in its batteries could be worked effectively. A model vessel of this form, 40 feet across, has been built, and sailed with the greatest success and under circumstances proving the value and the safety of the invention, details and illustrations of which were given. The class of Moody floating forts proposed would be not less than 200 feet from ray to ray, plated over the central battery with 9-inch armour backed by hollow stringers of not less than 10 inches in depth, and infilled with teak. The guns should be protected by a low vertical parapet with 14 or 15-inch plating. The main battery should contain at least eight 600-pounders, and it might be well to have a turret above this containing four 35-ton guns or 700-pounders to ensure gun-power above water if the battery should be submerged, even at the top of spring-tides. The height of the port-cills of the 'Hercules,' which are very lofty, is 11 feet above the water. The height of the port-cills of the proposed battery, when afloat, would be 12 feet, whilst the height of the turret-guns would be 26 feet; so that those guns would sweep and fire down upon the decks of the finest turret-ships and iron-clads.

Against ramming, these forts would be absolutely secure, the strength of their structure being enormous; and as all the beams and girders radiate from the centre, they give direct resistance in every direction to the blow. From the splay over of the horizontal rim of the battery it would not be possible for any attacking ship to get upon a ray to upset the fort, as has been most absurdly suggested; the real tendency of the battery when struck would be to gyrate out of the way. Taking the proposed fort as fighting against a ship of the 'Hercules' class, we should have for it a superiority of armour, and this superiority further increased by the angle at which the armour is inclined—an angle calculated to deflect the shot and not to permit its penetration; a superiority in guns; in stability and steadiness of platform; with no difficulty of opening ports and firing in any weather; and, finally, the advantage of being able to fight as a fixed fort after being sunk. The ship in action would be encumbered with fallen masts and spars and ropes entangling her screws, whilst the fort, moved by hydraulic power, would be completely free from those most serious troubles. Moreover, such deep-draught vessels as the 'Hercules' and our iron-clads generally could not follow an enemy's gun-boats over the shoals; but the battery, if necessary, could, whilst, on the other hand, if itself pressed hard, it could retire into shoal water.

The best means of protecting Liverpool and securing the immunity of its wealth are the placing of one of these powerful floating forts on or near Taylor's bank to command the junction of the Crosby and Formby channels leading into the long deep pool the Mersey makes at low water in Liverpool Bay; and another floating battery on or near the extremity of the East Hoyle Bank, to command the entrance to the Horse channel. By this disposition of the floating batteries the fight with an hostile fleet would be forced on at nine miles away from the town and docks, or, in other words, Liverpool and Birkenhead with their warehouses and shipping would be preserved from the reach of the heaviest guns. The waterways of the Victoria and Queen's and Old and New Formby channels could be planted with torpedoes, which would be protected by the guns of the floating forts; and the like could be done with the long pool of the Mersey meandering through the shoals in the bay, as also along the Horse and Rock channels under similar protection. Some few swift little steamers with Com-

mander Harvey's towing-torpedoes would, in addition, be useful to sweep the deeper waters.

On the Martini-Henry and Westley-Richards Rifles. *By* William P. Marshall, *C.E.*

The author stated that more than five years had elapsed since a Government Commission reported unanimously in favour of arming the whole British infantry with breech-loading guns; and in 1865 a Government advertisement invited patterns for the proposed arm. A committee of investigation examined the patterns sent in, and at the end of 1868 they recommended the adoption of the Martini breech mechanism, with the Henry rifling and the Boxer ammunition. The breech-closing arrangements in this combination were considered by practical men to be mechanically defective, but the bore of the barrel, the turn of the rifling, and the weight of the projectile gave excellent results as regards accuracy, trajectory, penetration, and rapidity of fire. In the breech-action the principle of the falling-block for opening the breech when loading, which was a previous American invention, was generally admitted to be the best that had been suggested, and so far the arm justified the decision of the committee; but the faults said to exist in it were in the striking-spring, the mode of lifting the falling-block, the arrangement of the trigger and locking-bolt, and the mode of attachment to the stock. All these were said to be so defective in principle, that they could not answer when made in large quantities, although a few rifles might be so made that no great fault should be detected in a limited trial, while the arms were new; and it was urged, consequently, that to adopt such a rifle would not be a mechanical credit to the country. Since the end of 1868 the committee has been endeavouring to perfect the arm, and several different patterns of it have been made at Enfield; but it still retains its inherent defects and objectionable features. In the Westley-Richards rifle, however, while all the approved points of the Martini-Henry rifle were retained, these defects in the lock mechanism had been removed by a very ingenious and simple application of the ordinary principles of construction of a gun-lock that have been confirmed by the long experience of previous arms. The barrel of both being satisfactory, the question was as to the lock; and the author considered that it was very desirable that further investigation should be made before the Government finally adopted any rifle for our army. In the Martini-Henry the most important defect was, that the falling-block was lifted by a lever acting near the centre of motion, which was mechanically objectionable, whereas in the Westley-Richards the falling-block was lifted by a longer lever acting at the extremity of the block, at the greatest distance from the centre of motion. In the Westley-Richards the striker for firing the cartridge was actuated by a long flat spring, and had $1\frac{1}{2}$ inch length of stroke, giving a sharp blow on the rear of the cartridge; but in the Martini-Henry a short stiff spiral spring was employed, giving only $3\frac{1}{4}$ inch length of stroke to the striker, which was objectionable mechanically, and not so certain in firing, nor so durable as the other arrangement. The above views of the respective merits of the two rifles were confirmed by some of our most eminent mechanical engineers, Messrs. Hick, Penn, Barlow, and Greenwood. Having stated these facts, the author went on to argue that, as the two kinds of rifle appeared to admit of equally safe and expeditious handling, and to be of equal shooting-power, the question between them resolved itself into one of mechanical construction. The military members of the committee had done their work well; the distinctive military requirements were satisfied by either weapon, and accuracy of shooting had probably reached its limit, as the results of the prize-shooting had not improved in the recent year's competitions. What was wanted was a fresh and independent committee, containing some experienced mechanical engineers, for the purpose of determining points of mechanism only. There was, however, another question of almost equal importance, and that was the ammunition. The first pattern of Boxer cartridge recommended by the committee had been withdrawn, and another, that was as defective, had been substituted for it. This had a case larger than was required to contain the proper charge, and consequently re-

quired an unnecessary enlargement of the breech-chamber; and the common solid brass cartridge-case now in general use in America and other countries would in many respects be preferable to it, especially because it can be readily obtained in large quantities, because its adoption would leave the chamber of the rifle of a minimum size, capable of being made larger if need should ever arise, and because the case was not destroyed in firing, and can be filled over and over again, and its use would thus be a source of great pecuniary saving to volunteers in their practice.

On Boiler-Explosions. *By* E. B. Marten, *C.E.*

At the Exeter Meeting it was suggested, in a report of a select committee, that inquests on boiler-explosions should be improved by making it compulsory that coroners should have scientific witnesses to assist the juries to ascertain the causes of explosions. From considerable experience in such investigations, the writer concluded that much more good would result from publishing independent reports to the Government by competent engineers, without interference with the ancient and useful coroner's inquest; and that the public would benefit more by the reports themselves than by the verdicts founded on them by juries, who, although well able to decide whether any one was criminally liable for a death, would be quite incompetent to discriminate between conflicting scientific opinion as to the causes of boiler-explosions.

On the Construction of Sewers in Running Sand. *By* Messrs. Reade *and* Goodison, *C.E., Liverpool.*

The authors related their experience in the construction of sewers at various places lying on the coast between Liverpool and Southport, a district mostly consisting of sand from 10 to 20 feet deep, thoroughly permeated with water and resting on a bed of moss and marl. In some places in the driest seasons the water-level is only a few feet below the surface. The difficulty of laying the inverts of the sewer true is immensely increased by the low gradients demanded by the general flatness of the country. They generally use fireclay pipe-sewers, from motives of economy and other reasons; and the jointing of these is very difficult in reaming sand, in consequence of the cement, even when covered with a clay lute, getting washed into the sewers before it has time to set. To overcome these difficulties they have introduced a subsoil-drain and pipe-rest (manufactured by Messrs. Brooke and Sons of Huddersfield) of the form of the letter , which is laid first in the bottom of the trench and jointed with clay like an ordinary pipe-sewer. This has the effect of lowering the subsoil-water, so that the sewer proper can be laid upon the moveable saddles or rests (fitting the curvature of the drains and the sewers) undisturbed by water or reaming sand. By these means the cement joints can be made perfect all round, and have time to set before the trench is filled up. True gradients are insured, as the pipes can be leisurely laid; and as the pipes are jointed over the *middle* of the subdrain a continuous foundation is secured. A more perfect drainage of the subsoil is also found to result, the general level of the water being reduced to nearly the level of the invert of the sewer. They have begun to use the subsoil-drains in the sewerage works they are carrying out at Birkdale, which includes a length of 10,000 yards of pipe-sewers. Methods for flushing the sewers with the subsoil-water were also described, and all the apparatus used by the authors in similar sanitary works.

On an Oblique Propeller. *By* Professor Osborne Reynolds.

Paddles for propelling ocean-steamers have been displaced by the screw; the great advantage of which is that it does not interfere with the sailing-qualities of the ship to the same extent as paddles do. It has, however, many disadvantages, as is shown by the frequent accidents which happen to screw-steamers. These are all due to its position at the end of the boat. Thus, it interferes with the action of the rudder, it makes the ship vibrate, it will not act when the ship is pitching,

and the long shaft is a source of endless trouble. It is with the hope to obviate these evils that the new propeller is proposed. This propeller is, in fact, an attempt to transfer the action of the screw to the middle of the ship. Prior attempts have been made to do this and have failed, not on their intrinsic merits, but incidentally through weakening the ship or requiring special and peculiar forms of ships.

Whatever demerits the proposed propeller may have, it must necessarily have the following merits:—

1. It is in the middle of the ship, and its action is not affected by pitching.
2. Its action cannot be affected by the rolling of the ship.
3. It will not interfere with the action of the rudder.
4. It will not interfere with the sailing-qualities of the ship.
5. It can be applied to ships of any form of section.
6. Its immersion will not be much altered by the lading of the ship.
7. For sailing, the propeller or the blades can be easily removed.
8. If applied to rams, they could strike with either end.

The experiments which have been made with the model, which is 5 feet long, have been very successful. It will steam at about two miles an hour, and it appears to go quite as well in rough water as it does in smooth. It goes quite straight without any rudder, and does not heel over from the effect of the propeller.

Description of the Propeller.—The plates which act on the water are fastened obliquely on to a flat endless chain, which is made so that it cannot be twisted. This chain passes round the middle of the ship, or it may pass across under the deck and then through the sides and down outside, and so under the bottom. In this way the chain will under-gird the ship in her middle, and the blades will act on all the water which comes within their length of the bottom or sides amidship. The draft of the ship will be increased by the length of the blades, which will be about one-seventh the entire draft. The chain is kept in its position by drums, which project a short distance beyond the skin of the ship. These drums must be so incased as to keep the water from getting into the ship. The chain is connected with the engines by means of one of these drums. Flanges on the drums prevent the chain working off them. In order to ascertain as far as possible the comparative merits of this propeller and the screw, one was designed for a large ship, the drawings of which are given in Scott Russell's 'Naval Architecture,' the size of all the parts being very carefully calculated, and then it was compared with the screw. The results of the comparison are given in the adjoining Table.

Dimensions of the Ship taken from Scott Russell's 'Naval Architecture.'

Length on load water-line	314 ft. 6 in.
Breadth, extreme	42 „ 3 „
Depth at side	31 „ 3 „
Tonnage, builder's measurement	2780 tons
Draft when laden	22 ft.
Nominal horse-power	600
Indicated „	2500
Speed in miles per hour	13·75

Dimensions of existing Machinery.

Length of screw-shaft	111 ft.
Diameter of screw-shaft	1 ft. 6 in.
Pitch of screw	34 ft.
Number of blades	3
Diameter of screw	19 ft.
Number of revolutions per minute	46
Slip in miles per hour	4
Approximate weight of screw and screw-shaft	50 tons
Friction arising from thrust-blocks is equivalent to an additional thrust of	0·25 ton
Ditto weight of shaft and screw	0·5 „
Thrust of ship	23 tons
Total increase of thrust equivalent to friction	0·75 ton

Dimensions of proposed Machinery.

Length of chain	123 ft.
Width	5 ft.
Diameter of pins	0 ft. $2\frac{1}{2}$ in.
Angle of blades	30°
Number of blades	11
Diameter of driving-pulley	14 ft.
Number of revolutions per minute	54
Length of blades	3 ft. 7 in.
Thickness of chain	0 „ 5 „
Slip in miles per hour	3
Tension of chain where greatest	23 tons
„ „ least	10 „
Weight of chain	13 tons
„ blades	2 „
„ pulleys and shafts	20 „
Weight to be compared with screw and screw-shaft	35 „
The friction arising from the motion of the pins as they pass round the drums if added to that thrust	680 lbs.
Ditto pressure of the drums on their bearings	500 „
Ditto thrust-blocks	290 „
Total increase in thrust equivalent to friction	0·64 ton

On Ocean Telegraphy. By Captain ROWETT.

On the Ash-pit System of Manchester. By Alderman R. RUMNEY.

What is the best method of dealing with the excrementitious matters of large towns is a question of difficult solution. It has been discussed annually at the British Association, not surely without benefit, but certainly without arriving at any general agreement.

As a contribution towards a solution of this question, a brief description of the method adopted in Manchester may not be without interest, and may serve either as an example or warning to other large towns similarly situated. When attention was first directed to the sanitary condition of towns, Manchester had scarcely any water-closets, but to every large house, and in every street, serving one family or many, were privies and open ash-pits of large dimensions situated at the back of the house, the privy-door opening into a yard very near the back door of the house, an ash-pit opening immediately behind, with a door opening into a passage forming the boundary between the streets or rows of houses, and through which door the refuse or contents of the ash-pit were from time to time emptied. These ash-pits received the rainfall and all the refuse of the house. The gases eliminated from the decomposing materials passed off at a low altitude, and might enter the yard or upper rooms of the house without difficulty.

The authorities of Manchester have at all times objected to the general use of water-closets in cottage-dwellings. In the first place, because they believed that in the limited space available in houses occupied by the working classes they would prove a greater nuisance than the privy and ash-pit outside; secondly, because of the loss of valuable manure which would be occasioned; and thirdly, because, looking at the rapid increase of population in the district and the limited area of the watershed, the time would come when all the water available would be required for domestic and manufacturing purposes, and could not be wasted in water-closets. Adhering, then, to the dry in opposition to the wet system, the corporation has for some time been engaged in the attempt to improve the existing privies and ash-pits, and to discover the best form to be adopted in all new property erected within the city. In 1868 the city council appointed a health-committee and officer of health, and placed the construction of privies and ash-pits

under the superintendence of this committee. At the same time the Artisans' Dwellings Act came into operation, and the provisions of this Act, with powers possessed by local Acts, have furnished the committee with the necessary authority for altering the old ash-pit and enforcing the construction of new ones according to the plans which have been adopted. In the construction of ash-pits the object of the committee was to prevent as far as possible the decomposition of the excreta, and consequent generation of gases passing off into the surrounding atmosphere; and as decomposition is accelerated by moisture, they determined that all ash-pits should be made dry, excluding the rainfall by covering them over, and the drainage from the yard by requiring the floor and walls to be made water-tight; they required also that the ashes from the pit should be placed daily in the ash-pit for the purpose of condensing, as far as possible, the ammoniacal and other gases, and preventing organic matter impregnating the air in the immediate vicinity. In addition to these arrangements it was foreseen that in summer time, when decomposition is most vigorous and the supply of neutralizing ashes most scanty, a closed ash-pit might become a greater nuisance than an open one; and a ventilating-shaft or chimney was determined upon, to be carried from the top of the ash-pit up to the side of, and a little above, the eaves of the house for the purpose of carrying off all the gases and light vapours and allowing them to mix with the surrounding atmosphere at an elevation which would not injuriously affect the inmates of the dwelling.

In attempting these improvements the committee met with considerable impediments—the covered ash-pit and flue had a hard struggle for existence; the council was sceptical, especially on the efficacy of the flue. It was to little purpose to assure the members that as the emanations from the ash-pit would, from the warm ashes of the kitchen and the fæcal matter, be of a higher temperature than the surrounding air, they must necessarily ascend and pass off at the highest point of egress, and, if there was no opening but the flue, then up the flue. The reply was, they might not do so. A flue had been connected with a covered ash-pit for a considerable time, and was found to be most effective; and it was urged that all other flues under similar circumstances would also be efficient, just as surely as heated air ascending one chimney would ascend all chimneys. The evidence was not deemed sufficient. The committee was authorized and required to have a number erected, and meanwhile the enforcement of the regulation was suspended. When at length the council, satisfied by the evidence adduced, authorized the committee to proceed, another obstacle presented itself. The property owners (that is, the owners of cottage property), having chiefly formed themselves into an association, rose in arms against the change; they declared that the cost of making the alteration would be £8 to £10, and that the rents must be advanced 1s. per week to carry out this new plan of the committee. They declared that, in the opinion of practical and scientific men, the ventilating-flue would be perfectly useless, that the noxious gases would not escape through the flue, but would overflow into the back yard, producing greater evils than any it was intended to remedy; and in a report of the executive committee of the "Associated Property Owners' Association," issued in December last, it is declared that, after nearly twelve months' experience and from consultations with gentlemen well able to form an opinion, they are more than ever convinced of its uselessness; and they promise at an early date to have the opinion of scientific men put in an official form in the nature of a report, which would be submitted to the health committee. What the opinion of these scientific men, upon which the property owners rest their case, may be cannot be ascertained, as no report has ever been presented; but it is worthy of remark, as illustrating the complexity of our legal procedure, that with all the powers possessed by the corporation in its many local Acts, and the stringent clauses of the Artisans' Dwellings Act, some of these property owners have succeeded in delaying the reconstruction of privies and ash-pits in connexion with dwellings declared by the officer of health to be unfit for human habitation for a period of nearly twelve months. Notwithstanding these obstructions, the committee has continued its operations. Every new house erected in the city is required to provide a water-tight covered ash-pit with ventilating-flue; and, taking the worst of the old ones, just about 270 have been reconstructed on the new plan, or as near

it as practicable. The results have been most satisfactory. I quote from a report of the health committee, giving to the council the result of an inspection of a number erected as a trial by the committee:—"It was found that the yards at the back of the houses, and the privies themselves, were entirely free from any offensive odours."

The contents of the ash-pits were dry; the surfaces of the yards were clean. When the hand was placed in the opening of the seat a current of air was perceptible; when a piece of brown paper was lighted and then blown out, so as to produce considerable smoke, and the paper then held over the grid in the wall of the privy, the smoke was strongly drawn down into the ash-pit; the same when applied to the seat of the privy. No smoke escaped at the opening of the seat, but all passed up the flue and mixed with the atmosphere above the roof of the house. The information from the occupants of the houses was most interesting. Some of them stated that whereas before the alterations were made they never opened the windows of the back bedroom in consequence of the stench that came into the room from the privies and ash-pits below, they now opened them daily, and got the rooms ventilated, and that, although formerly they were scarcely conscious of the disagreeable stench from their neighbours' premises, now their own were cleaner these fæcal smells affected them. The officer of health in his report, and as the result of careful inquiries, states that where the new form of ash-pit has been adopted, whether in old or new houses, there was not last summer a single case of diarrhœa or fever in the families of any of the occupants, although the former disease prevailed to a considerable extent in neighbouring families; the testimony of many house-owners is to the same effect. It is found that in new dwellings the cost of the new privy amd ash-pit is less than the old one; while in the reconstruction in old property it is much less than, in their fears, they had anticipated.

In the appendix to the report of the medical officer of the Privy Council just printed, Dr. Buchanan and Mr. Radcliffe made the following remarks on the Manchester system:—"We inspected a midden-closet arranged on this plan in a position where the advantage of careful superintendence was secured for it, built according to the requirements of the corporation—roofed, drained, and ventilated by a shaft carried up above the eaves of the adjoining building. The closet or privy used by a single family only opens into a small yard, 8 ft. 2 in. across at the widest part, and faces the living room of the cottage occupied by the family. A urine catch-pan was fixed beneath the privy-seat; the midden was two-thirds full of ashes and refuse, the latter cast in beneath the hinged seat, and no excrement was exposed to sight. As it contained fifteen months' accumulation of excrement, ashes, and house-refuse, its condition might not unfairly be regarded as similar to that of a closet emptied more frequently, but used by several families. There was no smell of excrement, nor, indeed, any marked odour about the privy, though on the same day (during a frost) in unimproved privies about the town there was notable stink. A current of air, as we determined by experiment, passed down through the aperture of the seat and upwards through the ventilating-shaft. The occupants of the house averred that no foul smell was at any time experienced by them from the closet. The removal of the contents of the ash-pits has been managed by the corporation since 1845. There are about 38,000 ash-pits of all sizes in the city, some large ones requiring to be emptied only once or twice a year; on an average, the contents will not be removed oftener than from two to three times in the course of a year. In the newly constructed ones, the size being so much reduced, the contents require to be removed more frequently; but the health-committee, regarding the matter in a sanitary point of view, not in an economical one, consider even the size of the new ones too large, and are gradually aiming at a size that will necessitate the removal of the contents every two or three weeks; but it is difficult to effect great changes all at once. Many people object to the emptying of the ash-pits frequently, or until they are filled with ashes, excrement, and refuse, and frequent removal can only be effected by limiting the space in which this refuse matter is contained. The ultimate aim, then, of the health-committee is to provide for every cottage a privy and small ash-pit, not sunk deep in the ground and perfectly water-tight, excluding the water from the yard and slops from the house, and covered over to exclude the rainfall—excluding also,

if possible, all refuse matter except the small ashes from the fire, and securing that these ashes shall be placed upon the excrement daily. In every case the ash-pit is placed as far from the entrance-door of the house as possible; and as in all new houses a yard-space of considerable size is required, generally the privy and ash-pit will not join up to the walls of the house, and in every case where it does so a strong flag is placed between the wall and the privy; and as the floor is sunk beneath the level of the floor of the dwelling, percolation will be entirely prevented. In addition, a ventilating-shaft must be carried up to the eaves of the house, the horizontal portion of which may form the coping of the separating wall between the two houses, and the area of this shaft must not be less than eighty-one square inches. A drain and grid are also required in the yard to carry off the water and slops of the house into the street sewers. Already upwards of 1500 have been erected under the supervision of the committee; the occupants are perfectly satisfied, and are constantly expressing their approval. The opposition of the property owners is subsiding; and although it will take many years to alter and improve the 30,000 old ones in the city, the committee and the officer of health feel confident that every step in this direction will tend to reduce the death rate and improve the health of the inhabitants."

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*Pneumatic Dispatch.—On Pneumatic Transmission through Tunnels and Pipes**. *By* ROBERT SABINE.

The author, after giving the result of investigations into the motions of bodies through tubes for this purpose, and the formulæ which he had arrived at, said that these would show that small pneumatic tubes could be worked more advantageously than large ones. The great convenience of and practical facilities for working small letter-carrying tubes have been amply proved by the extensive systems already laid down, in Paris, Berlin, London, and in other towns, as adjuncts to the telegraph services. Tubes of somewhat larger diameter, such as those proposed some years ago by Mr. A. E. Cowper for the more speedy distribution of metropolitan letters to the branch post-offices, would undoubtedly work satisfactorily. Even still larger tubes, if of moderate lengths, might also be found useful for a variety of special applications; for instance, in the transport of light materials between the different parts of a factory supplied with steam-power. He did not believe that a pneumatic line working through a long tunnel could, for passenger-traffic, ever compete in point of economy with locomotive railways. A pneumatic railway is essentially a rope railway. Its rope is elastic, it is true, but it is not light. Every yard run of it, in a tunnel large enough to carry passengers, would weigh more than $\frac{1}{4}$ cwt. And a rope, too, which has to be moved against considerable friction, in being compressed and moved wastes power by its liberation of heat. In a pneumatic tunnel, such as that proposed between England and France, in order to move a goods-train of 250 tons through at the rate of 25 miles an hour, it would be necessary to employ simultaneously a pressure of $1\frac{1}{2}$ lb. per square inch at one end, and a vacuum of $1\frac{1}{2}$ lb. per square inch at the other. The mechanical effect obtained with these combined (pressure and vacuum) would be consumed as follows:—

In accelerating the air	29	millions of foot-pounds.
In accelerating the train	12	
By friction of the air	5721	
By friction of the train......	330	

The resistance of the air, therefore, upon the walls of the tunnel would alone amount to 93 per cent. of the total mechanical effect employable for the transmission, while the really useful work would be only about $5\frac{1}{2}$ per cent. of it. And to compress and exhaust the air to supply the above items of expenditure of mechanical effect, engines would have to exert over 2000 horse-power at each end during the transmission, even on the supposition that the blowing-machinery returned an equivalent of mechanical effect such as has never yet been obtained. This

* Published *in extenso* in 'Engineering,' Sept. 23, 1870.

would not be an economical way of burning coals. It is desirable, nevertheless, from an engineering point of view, that the merits and demerits of pneumatic parcels-lines and pneumatic passenger-lines, which have been repeatedly suggested during the past half century, should be thoroughly investigated. The works of the Pneumatic Company in London, which are approaching completion, will happily settle the question as regards parcel-tubes; whilst the pneumatic passenger-railway, which, he was told, is in rapid course of construction under the streets of New York, will very soon either inaugurate a new era for city railways, or be written in the long list of unsuccessful experiments.

On a Submarine Ram and Gun. By MICHAEL SCOTT.

On Ships of War of moderate dimensions. By MICHAEL SCOTT.

On the Machinery and Working of Submarine Guns. By MICHAEL SCOTT.

On the Sewage of Liverpool and the Neighbourhood. By JAMES N. SHOOLBRED, *C.E.*

Liverpool at present contains about 520,000 inhabitants, and the suburban districts round it about 80,000 more; in all 600,000.

Of these by far the greatest number reside on a strip of land of no great breadth, running along the river Mersey and its estuary, and sloping gently down to them.

The close proximity of this rapid tidal stream, as well as the great facility afforded by it for the ready disposal of sewage and other refuse, will account for the predilection already shown for the water-closet over the privy system; and which predilection is annually becoming still more manifest. There are at present about 40,000 water-closets against 30,000 privies in the district.

The borough of Liverpool has expended about £900,000 in drainage and sewerage works. Of this, £300,000 may be set down as necessary for the conveyance of the contents of the water-closets. If this sum is capitalized, and a large allowance made for deterioration, then an annual amount of £60,000, or about 2*s*. 4*d*. per head of the population, may be taken as the cost of getting rid of the wet sewage of the town.

The midden, or dry sewage, together with the contents of the ash-pits attached to the houses having water-closets, amounts within the borough to about 140,000 tons in the year. This is removed by rail and by canal, and disposed of at a cost of about £21,000, while the amount realized by the sale of the refuse is only £8000; thus causing an annual loss to Liverpool of £13,000, or about 6*d*. per head of the population, in order to dispose of its dry sewage.

Several propositions have from time to time been made, especially since 1866, to utilize the wet sewage of the town by irrigation over some light soil about 10 miles distant to the northward, and near to the sea-coast; the land is of very considerable extent, and favourably situated for the purpose.

However, nothing as yet, beyond a trial experiment, so far successful, has been effected, and that upon a very small scale. Further steps with the same object, but in a different suburban district, are, it is understood, about to be taken.

The ready market which Liverpool in itself affords for the sale of the vegetable proceeds of this irrigation, and consequently for its success, is a further stimulus to reduce by this means the present annual cost to Liverpool in getting rid of its sewage and refuse.

Liverpool may, however, be said even now to be much favoured by nature in this matter; inasmuch as the burden falls much more lightly upon it than upon many other large towns, which have enforced against them by the arm of the law the unpleasant consequences this question may sometimes bring with it.

On Mechanical Stoking. *By* James Smith.

On a New Safety-lamp. *By* W. E. Teale.

Description of the Hydraulic Bucketting-engine for the Herculaneum Graving-dock, Liverpool. *By* Percy Westmacott, *C.E.*

The application of hydraulic power to gates and capstans &c. having already been decided upon for these docks, it was considered expedient to contrive the emptying of the graving-docks in conjunction with this same system, and thus save the erection of another steam-engine and plant for this special service, and at the same time secure a ready means of applying power at all times, especially to severe leaks. Some arrangement, too, was required that would overcome the inconveniences experienced in dealing with water charged with rubbish from graving-docks. The result was the construction of a machine upon a principle of bucketting large quantities of water at a time—devoid of clack-valves, gratings, or other parts liable to choking or injury by floating matter, and that could be lifted clean out of the water to give free access to all parts when required. By this principle the same weight of water is discharged at each stroke, and thus no undue loss arises from the application of a constant hydraulic pressure; nor does the strain upon the parts or the conditions in working vary with the fall of water in the dock. A scooped-shaped bucket attached to a piston-rod is plunged at an angle of slight resistance into the water, and by a self-acting arrangement is turned round at the proper level, filled, raised, and discharged over an apron. The bucket holds $14\frac{1}{2}$ tons of water. Two discharging-levels are provided.

It will be seen that when the bucket is up all essential working parts are out of the water, and therefore quite free of access.

The minimum lift at the high-level discharge is 7 ft., and the maximum 23 ft.

The usual average speed of the bucket in plunging or lifting is about 3 ft. per second.

The coefficient of effect obtained by this engine is as follows:—At 7 ft. (minimum) lift ·4; at 23 ft. (maximum) lift ·6; average ·54. The loss occasioned by the choking of passages and gagging of valves or paddles is altogether avoided by this system, which, for this reason, is peculiarly well adapted for sewerage purposes.

On Street Management. *By* F. Wilson.

APPENDIX.

On the Vegetable Products of Central Africa. *By* Lieut.-Colonel J. A. Grant, *C.B.*, *F.L.S.*

The country embraced in the remarks made by the author comprises that traversed by the late Captain Speke in his journey to the sources of the Nile, 1860–63. The plants collected were made over to the Royal Herbarium, Kew, and were classified there by Dr. T. Thomson. They are to be described in the 'African Flora' by Professors Oliver, Lawson, Masters, and others. Notes and drawings of the majority of the specimens were made on the spot, and from these notes the author had compiled this paper. He described, in the first place, the forests of the low lands, which consist of trees which are commercially of small importance. The species are numerous, and for nearly all of them the natives seem to have names. The author then described at considerable length the uses made by the natives of the roots, bark, leaves, fruits, seeds, and grains of numerous trees, shrubs, and plants as medicines, foods, household utensils, fishing-implements, and the like.

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[*An asterisk* (*) *signifies that no abstract of the communication is given.*]

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Together with the Transactions of the Sections, Rev. W. Vernon Harcourt's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TENTH MEETING, at Glasgow, 1840, *Published at* 15*s.* (Out of Print.)

Contents:—Rev. B. Powell, Report on the recent Progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science;—J. D. Forbes, Supplementary Report on Meteorology;—W. S. Harris, Report on Prof. Whewell's Anemometer, now in operation at Plymouth;—Report on "The Motion and Sounds of the Heart," by the London Committee of the British Association, for 1839–40;—Prof. Schönbein, an Account of Researches in Electro-Chemistry;—R. Mallet, Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron and Steel;—R. W. Fox, Report on some Observations on Subterranean Temperature;—A. F. Osler, Report on the Observations recorded during the years 1837, 1838, 1839, and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham;—Sir D. Brewster, Report respecting the two Series of Hourly Meteorological Observations kept at Inverness and Kingussie, from Nov. 1st, 1838 to Nov. 1st, 1839;—W. Thompson, Report on the Fauna of Ireland: Div. *Vertebrata*;—C. J. B. Williams, M.D., Report of Experiments on the Physiology of the Lungs and Air-Tubes;—Rev. J. S. Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances.

Together with the Transactions of the Sections, Mr. Murchison and Major E. Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE ELEVENTH MEETING, at Plymouth, 1841, *Published at* 13*s.* 6*d.*

Contents:—Rev. P. Kelland, on the Present state of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G. L. Roupell, M.D., Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year;—Report of a Committee appointed for the purpose of superintending the scientific cooperation of the British Association in the System of Simultaneous Observations in Terrestrial Magnetism and Meteorology;—Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord;—Report of a Com-

mittee to superintend the reduction of Meteorological Observations;—Report of a Committee for revising the Nomenclature of the Stars;—Report of a Committee for obtaining Instruments and Registers to record Shocks and Earthquakes in Scotland and Ireland;—Report of a Committee on the Preservation of Vegetative Powers in Seeds;—Dr. Hodgkin, on Inquiries into the Races of Man;—Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable expense of such Experiments, and to draw up Directions for Observers in such circumstances;—R. Owen, Report on British Fossil Reptiles;—Reports on the Determination of the Mean Value of Railway Constants;—D. Lardner, LL.D., Second and concluding Report on the Determination of the Mean Value of Railway Constants;—E. Woods, Report on Railway Constants;—Report of a Committee on the Construction of a Constant Indicator for Steam-Engines.

Together with the Transactions of the Sections, Prof. Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester, 1842, *Published at* 10*s*. 6*d*.

CONTENTS:—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—J. Richardson, M.D., Report on the present State of the Ichthyology of New Zealand;—W. S. Harris, Report on the Progress of Meteorological Observations at Plymouth;—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections;—Report of the Committee for the Preservation of Animal and Vegetable Substances;—Lyon Playfair, M.D., Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed "to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;"—Report of a Committee on the Vital Statistics of large Towns in Scotland;—Provisional Reports, and Notices of Progress in special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s*.

CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach, on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W.

Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at* £1.

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds;—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at* 12*s*.

CONTENTS:—Seventh Report of a Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at* 15*s*.

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical

Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—J. Percy, M.D., Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18s.

Contents:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Arian and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9s.

Contents:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lt.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10s.

Contents:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and

Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at* 15s. (Out of Print.)

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840 to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849;—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at* 16s. 6d.

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds;—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs;—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850 to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at* 15s.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s.* 6*d.*

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53; —James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations; —John P. Bell, M.D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast; First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued); —Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery;—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s.*

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55; —Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s.*

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report.

on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena: Part I.;—Dr. T. Wright on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage;—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at* 15*s*.

CONTENTS:—A. Cayley, Report on the Recent Progress of Theoretical Dynamics;—Sixteenth and final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, De quelques Transformations de la Somme $\Sigma_0^{t^{-\alpha}} \frac{\alpha^{t|+1}\beta^{t|+1}\delta^{t'+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t+1}}$, α étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $a^{t|+1}$ désignant le produit des t facteurs $a\ (a+1)\ (a+2)$ &c....$(a+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—John P. Hodges, M.D., on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, C.E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Professor W. A. Miller, M.D., on Electro-Chemistry;—John Simpson, R.N., Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargreave, LL.D., on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Professor James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, M.A., Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at* 20*s*.

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the

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PROCEEDINGS of the THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at* £1 5s.

Contents:—J. G. Jeffreys, Report on Dredging among the Channel Isles;—F. Buckland Report on the Cultivation of Oysters by Natural and Artificial Methods;—Report of the Committee for exploring Kent's Cavern;—Report of the Committee on Zoological Nomenclature;—Report on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Interim Report on the Resistance of Water to Floating and Immersed Bodies;—Report on Observations of Luminous Meteors;—Report on Dredging on the Coast of Aberdeenshire;—J. Glaisher, Account of Three Balloon Ascents;—Interim Report on the Transmission of Sound under Water;—G. J. Symons, on the Rainfall of the British Isles;—W. Fairbairn, on the Strength of Materials considered in relation to the Construction of Iron Ships;—Report of the Gun-Cotton Committee;—A. F. Osler, on the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and Birmingham;—B. W. Richardson, Second Report on the Physiological Action of certain of the Amyl Compounds;—Report on further Researches in the Lingula-flags of South Wales;—Report of the Lunar Committee for Mapping the Surface of the Moon;—Report on Standards of Electrical Resistance;—Report of the Committee appointed to communicate with the Russian Government respecting Magnetical Observations at Tiflis;—Appendix to Report on the Distribution of the Vertebrate Remains from the North Staffordshire Coal-field;—H. Woodward, First Report on the Structure and Classification of the Fossil Crustacea;—H. J. S. Smith, Report on the Theory of Numbers, Part VI.;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—A. G. Findlay, on the Bed of the Ocean;—Professor A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

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ASSISTANT GENERAL SECRETARY.

GEORGE GRIFFITH, Esq., M.A., Harrow.

GENERAL TREASURER.

WILLIAM SPOTTISWOODE, Esq., M.A., F.R.S., F.R.G.S., 50 Grosvenor Place, London, S.W.

AUDITORS.

G. Busk, Esq., F.R.S.
Professor M. Foster, M.D., F.L.S.
J. Gwyn Jeffreys, Esq., F.R.S.

LIST OF MEMBERS

OF THE

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

1871.

* indicates Life Members entitled to the Annual Report.
§ indicates Annual Subscribers entitled to the Annual Report.
‡ indicates Subscribers not entitled to the Annual Report.
Names without any mark before them are Life Members not entitled to the Annual Report.
Names of Members whose addresses are incomplete or not known are in *italics*.

Notice of changes of Residence should be sent to the Assistant General Secretary, 22 Albemarle Street, London, W.

Year of Election.

Abbatt, Richard, F.R.A.S. Marlborough-house, Woodberry Down, Stoke Newington, London, N.
1866. ‡Abbott, George J., United States Consul, Sheffield and Nottingham.
1863. *Abel, Frederick Augustus, F.R.S., F.C.S., Director of the Chemical Establishment of the War Department, Royal Arsenal, Woolwich.
1856. ‡Abercrombie, John, M.D. 13 Suffolk-square, Cheltenham.
1863. *Abernethy, James. 2 Delahay-street, Westminster, London, S.W.
1860. §Abernethy, Robert. Ferry-hill, Aberdeen.
1854. ‡Abraham, John. 87 Bold-street, Liverpool.
1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.
Acland, Henry W. D., M.A., M.D., LL.D., F.R.S., F.R.G.S., Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.
Acland, Sir Thomas Dyke, Bart., M.A., D.C.L., F.R.S., F.G.S., F.R.G.S. Killerton, Devon.
1860. ‡Acland, Thomas Dyke, M.A., D.C.L., M.P. Sprydoncote, Exeter and Athenæum Club, London, S.W.
Adair, John. 13 Merrion-square North, Dublin.
*Adair, Colonel Sir Robert A. Shafto, F.R.S. 7 Audley-square, London, W.
*Adams, John Couch, M.A., D.C.L., F.R.S., F.R.A.S., Director of the Observatory and Lowndean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.

Year of Election.

1869. *Adams, William Grylls, M.A., F.G.S., Professor of Natural Philosophy and Astronomy in King's College, London, W.C.
Adderley, The Right Hon. Sir Charles Bowyer, M.P. Hams-hall Coleshill, Warwickshire.
Adelaide, Augustus Short, D.D., Bishop of. South Australia.
1860. *Adie, Patrick. Grove Cottage, Barnes, London, S.W.
1865. *Adkins, Henry. The Firs, Edgbaston, Birmingham.
1845. ‡Ainslie, Rev. G., D.D., Master of Pembroke College. Pembroke Lodge, Cambridge.
1864. *Ainsworth, David. The Flosh, Cleator, Whitehaven.
Ainsworth, Peter. Smithills Hall, Bolton.
1842. *Ainsworth, Thomas. The Flosh, Cleator, Whitehaven.
1859. ‡Airlie, The Right Hon. The Earl of, K.T. Holly Lodge, Campden Hill, London, W.; and Airlie Castle, Forfarshire.
Airy, George Biddell, M.A., LL.D., D.C.L., F.R.S., F.R.A.S., Astronomer Royal. The Royal Observatory, Greenwich.
1855. ‡Aitkin, John, M.D. 21 Blythswood-square, Glasgow.
Akroyd, Edward, M.P. Bankfield, Halifax.
1861. *Alcock, Ralph. 47 Nelson-street, Oxford-street, Manchester.
1862. ‡Alcock, Sir Rutherford. The Athenæum Club, Pall Mall, London.
1861. ‡Alcock, Thomas, M.D. Side Brook, Salemoor, Manchester.
*Aldam, William. Frickley Hall, near Doncaster.
Alderson, Sir James, M.A., M.D., D.C.L., F.R.S., Pres. Roy. Coll. Physicians, Consulting Physician to St. Mary's Hospital. 17 Berkeley-square, London, W.
1857. ‡Aldridge, John, M.D. 20 Ranelagh-road, Dublin.
1859. ‡Alexander, Colonel Sir James Edward, K.C.L.S., F.R.A.S., F.R.G.S. Westerton, Bridge of Allan, N. B.
1858. ‡Alexander, William, M.D. Halifax.
1850. ‡Alexander, William Lindsay, D.D., F.R.S.E. Edinburgh.
1851. ‡Alexander, W. H. Bank-street, Ipswich.
1869. ‡*Alger, T. L.*
1867. ‡Alison, George L. C. Dundee.
1863. ‡Allan, Miss. Bridge-street, Worcester.
1859. ‡Allan, Alexander. Scottish Central Railway, Perth.
1862. ‡Allan, James, M.A., Ph.D. School of Practical Science, Sheffield.
Allan, William. 22 Carlton-place, Glasgow.
1861. ‡Allen, Richard. Didsbury, near Manchester.
Allen, William. 50 Henry-street, Dublin.
1852. *Allen, William J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
*Allis, Thomas, F.L.S. Osbaldwick Hall, near York.
*Allman, George J., M.D., F.R.S. L. & E., M.R.I.A., 20 Gloucester Road, Regent's Park, London, N.W.
1868. ‡*Allon, Rev. H.*
1866. ‡Allsopp, Alexander. The Park, Nottingham.
1844. *Ambler, Henry. The Granges, near Halifax.
*Amery, John, F.S.A. Manor House, Eckington, Pershore.
1855. ‡Anderson, Alexander D., M.D. 159 St. Vincent-street, Edinburgh.
1855. ‡Anderson, Andrew. 2 Woodside-crescent, Glasgow.
1850. ‡Anderson, Charles William. Cleadon, South Shields.
1852. ‡Anderson, Sir James. Glasgow.
1855. ‡*Anderson, James. Springfield Blantyre, Glasgow.*
1850. ‡Anderson, John. 31 St. Bernard's-crescent, Edinburgh.
1859. ‡Anderson, Patrick. 15 King-street, Dundee.

Year of
Election.

1850. ‡Anderson, Thomas, M.D., Professor of Chemistry in the University of Glasgow.
1870. §Anderson, Thomas Darnley. West Dingle, Liverpool.
1853. *Anderson, William (Yr.). Linktown, Kirkcaldy, Scotland.
*Andrews, Thomas, M.D., F.R.S., M.R.I.A., F.C.S., Vice-President of, and Professor of Chemistry in, Queen's College, Belfast.
1857. ‡Andrews, William. The Hill, Monkstown, Co. Dublin.
1859. ‡Angus, John. Town House, Aberdeen.
*Ansted, David Thomas, M.A., F.R.S., F.G.S., F.R.G.S. 33 Brunswick-square, London, W.C.
Anthony, John, M.D. Caius College, Cambridge.
1868. ‡Anstie, Francis E., M.D. 16 Wimpole-street, London, W.
Apjohn, James, M.D., F.R.S., M.R.I.A., Professor of Chemistry, Trinity College, Dublin. 32 Lower Bagot-street, Dublin.
1863. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.
1859. ‡*Arbuthnot, C. T.*
1870. §Archer, Francis, jun. 3 Brunswick-street, Liverpool.
1855. *Archer, Thomas C., F.R.S.E., Director of the Museum of Science and Art. 9 Argyll-place, Edinburgh.
1851. ‡Argyll, The Duke of, K.T., LL.D., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London; and Inverary, Argyllshire.
1865. ‡Armitage, J. W., M.D. 9 Huntriss-row, Scarborough.
1861. §Armitage, William. 7 Meal-street, Mosley-street, Manchester.
1867. *Armitstead, George, M.P. Errol Park, Errol, by Dundee.
Armstrong, Thomas. Higher Broughton, Manchester.
1857. *Armstrong, Sir William George, C.B., LL.D., D.C.L., F.R.S. 8 Great George-street, London, S.W.; and Elswick Works, Newcastle-upon-Tyne.
1856. ‡Armstrong, William Jones, M.A. Mount Irwin, Tynna, Co. Armagh.
1868. ‡Arnold, Edward. Prince of Wales-road, Norwich.
Arnott, Neil, M.D., F.R.S., F.G.S. 2 Cumberland-terrace, Regent's Park, London, N.W.
1870. §Arnott, Thomas Reid. 2 Church Road, Seaforth, Liverpool.
1864. §Arrowsmith, John, F.R.A.S., F.R.G.S. 35 Hereford-square, South Kensington, London, S.W.
1853. *Arthur, Rev. William, M.A. Methodist College, Belfast.
1870. *Ash, Linnington. Holsworthy, North Devon.
1842. *Ashton, Thomas, M.D. 8 Royal Wells-terrace, Cheltenham.
Ashton, Thomas. Ford Bank, Didsbury, Manchester.
1866. ‡Ashwell, Henry. Mount-street, New Basford, Nottingham.
*Ashworth, Edmund. Egerton Hall, Turton, near Bolton.
Ashworth, Henry. Turton, near Bolton.
1861. ‡Aspland, Alfred. Dukinfield, Ashton-under-Lyne.
Aspland, Algernon Sydney. Glamorgan House, Durdham Down, Bristol.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Thomas. 4 Elm-court, Temple, London, E.C.
1858. ‡Atherton, Charles. Sandover, Isle of Wight.
1866. §Atherton, J. H., F.C.S. Long-row, Nottingham.
1865. ‡Atkin, Alfred. Griffin's-hill, Birmingham.
1861. ‡Atkin, Eli. Newton Heath, Manchester.
1865. *Atkinson, Edmund, F.C.S. 7 The Terrace, Sandhurst, Farnborough Station.
1863. *Atkinson, G. Clayton. Wylam Hall, Northumberland.
1858. *Atkinson, John Hastings. 14 East Parade, Leeds.
1842. *Atkinson, Joseph Beavington. Stratford House, 13 Carlisle-terrace, Kensington, London, W.

Year of Election.

1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. *Atkinson, J. R. W. 37 Upper George-street, Bryanstone-square, London, W.
Atkinson, William. Ashton Hayes, near Chester.
1863. *Attfield, Dr. J. 17 Bloomsbury-square, London, W.C.
**Auldjo, John, F.G.S.*
1859. ‡*Austin, Alfred.*
1860. *Austin-Gourlay, Rev. William E. C., M.A. Stoke Abbott Rectory, Beaminster, Dorset.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1865. *Avery, William Henry. Norfolk-road, Edgbaston, Birmingham.
1867. §Avison, Thomas, F.S.A. Fulwood Park, Liverpool.
1853. *Ayrton, W. S., F.S.A. Saltburn-by-the-Sea.

Babbage, B. H. 1 Dorset-street, Manchester-square, London, W.
*Babbage, Charles, M.A., F.R.S. L. & E., Hon. M.R.I.A., F.R.A.S. 1 Dorset-street, Manchester-square, London, W.
*Babington, Charles Cardale, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Trumpington-road, Cambridge.
Bache, Rev. Samuel. 44 Frederick-street, Edgbaston, Birmingham.
1845. ‡Back, Rear-Admiral Sir George, D.C.L., F.R.S., F.R.G.S. 109 Gloucester-place, Portman-square, London, W.
1867. *Bagg, Stanley Clark. Fairmount Villa, Montreal, Canada.
Backhouse, Edmund. Darlington.
1863. ‡Backhouse, J. W. Sunderland.
Backhouse, Thomas James. Sunderland.
**Baddeley, Captain Frederick H., R.E.* 10 *Sutherland Place, Westbourne Grove, Bayswater.*
1870. §Bailey, F. J. 51 Grove-street, Liverpool.
Bailey, Samuel. Sheffield.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1866. ‡Baillon, Andrew. St. Mary's Gate, Nottingham.
1866. ‡Baillon, L. St. Mary's Gate, Nottingham.
1857. ‡Baily, William Hellier, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 51 Stephen's Green, and 24 Kenilworth-square North, Dublin.
*Bain, Richard. Care of Williams, Foster, & Co., St. Clement's House, Clement's-lane, London, E.C.
1865. ‡Bain, Rev. W. J. Wellingborough.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*Baines, Edward, M.P. 28 Grosvenor-street West, London, S.W.; and Headingley Lodge, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1865. §Baines, Thomas, F.R.G.S. 35 Austen-street, King's Lynn, Norfolk.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1866. §Baker, Francis B. Arboretum Street, Nottingham.
1858. *Baker, Henry Granville. Bellevue, Horsforth, near Leeds.
1865. ‡Baker, James P. Wolverhampton.
1861. *Baker, John. Gatley-hill, Cheadle, Cheshire.
1861. *Baker, John. (R. Brooks & Co., St. Peter's Chambers, Cornhill, London, C.E.)
1865. ‡Baker, Robert L. Barham House, Leamington.
1847. ‡Baker, Thomas B. Lloyd. Hardwick-court, Gloucester.
1849. *Baker, William. 63 Gloucester-place, Hyde Park, London, W.

Year of Election.

1863. §Baker, William. 6 Taptonville, Sheffield.
1845. ‡Bakewell, Frederick. 6 Haverstock-terrace, Hampstead, London, N.W.
1860. §Balding, James, M.R.C.S. Barkway, Royston, Hertfordshire.
1851. *Baldwin, The Hon. Robert, H.M. Attorney-General. Spadina, Co. York, Upper Canada.
*Balfour, John Hutton, M.D., M.A., F.R.S. L. & E., F.L.S., Professor of Botany in the University of Edinburgh. 27 Inverleith-row, Edinburgh.
*Ball, John, F.R.S., F.L.S., M.R.I.A. 24 St. George's Road, Eccleston Square, London, S.W.
1866. *Ball, Robert Stawell, M.A., Professor of Applied Mathematics and Mechanics in the Royal College of Science of Ireland. 47 Wellington-place, Upper Leeson-street, Dublin.
1863. ‡Ball, Thomas. Bramcote, Nottingham.
*Ball, William. Bruce-grove, Tottenham, London, N.; and Rydall, Ambleside, Westmoreland.
1870. §Balmain, W. H. Spring Cottage, Great St. Helens.
1869. ‡Bamber, Henry K. 5 Westminster Chambers, Victoria-street, Westminster, S.W.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1861. ‡Bannerman, James Alexander. Limefield House, Higher Broughton, near Manchester.
1870. §Banister, Rev. William, B.A. St. James's Mount, Liverpool.
1866. ‡Barber, John. Long-row, Nottingham.
1861. *Barbour, George. Edge Hall, Malpas, Chester.
1859. ‡Barbour, George F. Bouskeid, Edinburgh.
*Barbour, Robert. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
Barclay, Charles, F.S.A., M.R.A.S. Bury-hill, Dorking.
Barclay, James. Catrine, Ayrshire.
1852. *Barclay, J. Gurney. Walthamstow, Essex.
1860. *Barclay, Robert. Oak Hall, Wanstead, Essex.
1868. *Barclay, W. L. Knott's Green, Leyton, Essex.
1863. *Barford, James Gale. Wellington College, Berkshire.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgeford Rectory, Notts.
1857. ‡Barker, John, M.D., Curator of the Royal College of Surgeons of Ireland. Waterloo Road, Dublin.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. §Barkly, Sir Henry, K.C.B., F.R.S. Bath.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
Barlow, Peter. 5 Great George-street, Dublin.
1857. ‡Barlow, Peter William, F.R.S., F.G.S. 8 Eliott-place, Blackheath, S.E.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1864. *Barneby, John H. Brockhampton Park, Worcester.
1868. §Barnes, Richard H. 40 Kensington Park Gardens, London, W.
*Barnes, Thomas, M.D., F.R.S.E. Bunker's Hill, Carlisle.
Barnes, Thomas Addison. 40 Chester Street, Wrexham.
*Barnett, Richard, M.R.C.S. Avon-side, Coten End, Warwickshire.
1859. ‡Barr, Major-General, Bombay Army. Culter House, near Aberdeen. (Messrs. Forbes, Forbes & Co., 9 King William-street, London.)
1861. *Barr, William R. Heaton Lodge, Heaton Mersey, near Manchester.
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.

Year of
Election.

1852. ‡Barrington, Edward. Fassaroe Bray, Co. Wicklow.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1858. ‡Barry, Rev. A., D.D., D.C.L., Principal of King's College, London, W.C.
1862. *Barry, Charles. Lapswood, Sydenham-hill, Kent, S.E.
Barstow, Thomas. Garrow-hill, near York.
1858. *Bartholomew, Charles. Broxholme, Doncaster.
1855. ‡Bartholomew, Hugh. New Gas-works, Glasgow.
1858. *Bartholomew, William Hamond. Albion Villa, Spencer-place, Leeds.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1857. ‡Barton, Folloit W. Clonelly, Co. Fermanagh.
1852. ‡Barton, James. Farndreg, Dundalk.
*Barton, John. Bank of Ireland, Dublin.
1864. ‡Bartrum, John S. 41 Gay-street, Bath.
1870. §Baruchson, Arnold. Blundell Sands, near Liverpool.
1858. *Barwick, John Marshall. Albion-place, Leeds; and Glenview, Shipley, near Leeds.
*Bashforth, Rev. Francis, B.D. 15 Campbell-terrace, Plumstead, Kent, S.E.
1861. ‡Bass, John H., F.G.S. 287 Camden-road, London, N.
1866. *Bassett, Henry. 12 South-crescent, Bedford-square, London, W.C.
1866. ‡Bassett, Richard. Pelham-street, Nottingham.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1848. ‡Bate, C. Spence, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
Bateman, James, M.A., F.R.S., F.L.S., F.H.S. Biddulph Grange, near Congleton, Staffordshire.
1842. *Bateman, John Frederic, C.E., F.R.S., F.G.S. 16 Great George-street, London, S.W.
1864. §Bates, Henry Walter, Assist.-Sec. R.G.S. 15 Whitehall-place, London, S.W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1851. ‡Bath and Wells, Lord Arthur Hervey, Lord Bishop of.
1863. *Bathurst, Rev. W. H. Lydney, Gloucestershire.
1869. ‡Batten, John Winterbotham. 35 Palace Gardens-terrace, Kensington, London, S.W.
1863. §Bauerman, Henry, F.G.S. 22 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1867. *Baxter, Sir David, Bart. Kilmaron, Cupar, Fifeshire.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, John B. Craig Tay House, Dundee.
1870. §Baxter, R. Dudley, M.A. 6 Victoria-street, Westminster, S.W., and Hampstead.
1867. ‡Baxter, William Edward, M.P. Ashcliffe, Dundee.
1851. *Bayley, George. 2 Cowper's-court, Cornhill, London, E.C.
1866. ‡Bayley, Thomas. Lenton, Nottingham.
1854. ‡Baylis, C. O., M.D. 22 Devonshire Road, Claughton, Birkenhead.
Bayly, John. 1 Brunswick-terrace, Plymouth.
1868. ‡Bayes, William, M.D. Brunswick Lodge, Newmarket-road, Norwich.
1860. *Beale, Lionel S., M.D., F.R.S., Professor of Physiology and of General and Morbid Anatomy in King's College, London. 61 Grosvenor-street, London, W.
1833. *Beamish, Richard, F.R.S. Woolston Lawn, Woolston, Southampton.
1861. §Bean, William. Alfreton, Derbyshire.
1870. §Beard, Rev. Charles. 13 South Hill Road, Toxteth Park, Liverpool.
1866. *Beardmore, Nathaniel, C.E., F.G.S. 30 Great George-st., London, S.W.
*Beatson, William. Chemical Works, Rotherham.

Year of
Election.

1855. *Beaufort, William Morris, F.R.G.S., M.R.A.S. Oriental Club, Hanover-square, London, W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Capt. George G. Army and Navy Club, Pall Mall, London, S.W.
1859. *Beck, Joseph, F.R.A.S. 31 Cornhill, London, E.C.
1851. ‡*Becker, Ernest, Ph.D. Darmstadt.*
1864. §Becker, Miss Lydia E. 28 Jackson's-row, Albert Sq., Manchester.
1860. ‡Beckles, Samuel H., F.R.S., F.G.S. 9 Grand Parade, St. Leonards-on-Sea.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §Beddoe, John, M.D. Clifton, Bristol.
1854. ‡*Bedford, James, Ph.D.*
1846. ‡Beke, Charles T., Ph.D., F.S.A., F.R.G.S. Bekesbourne House, near Canterbury, Kent.
1865. *Belavenetz, I., Captain of the Russian Imperial Navy, F.R.I.G.S., M.S.C.M.A., Superintendent of the Compass Observatory, Cronstadt. (Care of Messrs. Baring Brothers, Bishopsgate-street, London, E.C.)
1847. *Belcher, Vice-Admiral Sir Edward, K.C.B., F.R.A.S., F.R.G.S. 22A Connaught-square, London, W.
1850. ‡Bell, Charles, M.D. 3 St. Colme-street, Edinburgh.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Christ's Hospital, London, E.C.
1855. ‡Bell, Capt. Henry. Chalfont Lodge, Cheltenham.
1862. *Bell, Isaac Lowthian. The Hall, Washington, Co. Durham.
1870. §Bell, J. Carter. Gilda Brooth, Eccles, Manchester.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1859. ‡Bell, Robert, jun. 3 Airlie-place, Dundee.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
Bell, Thomas, F.R.S., F.L.S., F.G.S., Professor of Zoology, King's College, London. The Wakes, Selborne, near Alton, Hants.
1863. *Bell, Thomas. The Minories, Jesmond, Newcastle-on-Tyne.
1867. ‡Bell, Thomas. Belmont, Dundee.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1854. ‡Bellhouse, William Dawson. 1 Park-street, Leeds.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1866. *Belper, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.G.S. 88 Eaton-square, London, S.W.; and Kingston Hall, Derby.
1864. *Bendyshe, T. The Library, King's College, Cambridge.
1870. §Bennett, Alfred W., M.A., B.Sc., F.L.S. 3 Park Village East, Regent's Park, London, N.W.
1850. ‡Bennett, John Hughes, M.D., F.R.S.E., Professor of Institutes of Medicine in the University of Edinburgh. 1 Glenfinlas-street, Edinburgh.
1870. *Bennett, William. Heyshem Tower, Lancaster.
1870. *Bennett, William, jun. Sir Thomas's Buildings, Liverpool.
1852. *Bennoch, Francis. The Knoll, Blackheath, Kent, S.E.
1857. ‡Benson, Charles. 11 Fitzwilliam-square West, Dublin.
Benson, Robert, jun. Fairfield, Manchester.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. §Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.
1848. ‡Bentham, George, F.R.S., Pres. L.S. 25 Wilton-place, Knightsbridge. London, S.W.
1842. Bentley, John. 9 Portland-place, London, W.

Year of Election.

1863. §Bentley, Robert, F.L.S., Professor of Botany in King's College. 55 Clifton-road, St. John's-wood, London, N.W.
1868. ‡Berkeley, Rev. M. J., M.A., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1848. ‡Berrington, Arthur V. D. Woodlands Castle, near Swansea.
1866. §Berry, Rev. Arthur George. Monyash Parsonage, Bakewell, Derbyshire.
1870. §Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A. St. John's College, Cambridge.
1865. *Bessemer, Henry. Denmark-hill, Camberwell, London, S.E.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Rear-Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1859. ‡Beveridge, Robert, M.B. 20 Union-street, Aberdeen.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.
*Bickerdike, Rev. John, M.A. St. Mary's Vicarage, Leeds.
1870. §Bickerton, A. W., F.C.S. Oak House, Belle View Road, Southampton.
1868. ‡Bidder, George Parker, C.E., F.R.G.S. 24 Great George-street, Westminster, S.W.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1864. ‡Biggs, Robert. 17 Charles-street, Bath.
1855. ‡Billings, Robert William. 4 St. Mary's-road, Canonbury, London, N.
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.; and Chislehurst, Kent.
1842. Binney, Edward William, F.R.S., F.G.S. 40 Cross-street, Manchester.
Birchall, Edwin. College-house, Bradford.
Birchall, Henry. Airedale Cliff, Newley, Leeds.
1866. *Birkin, Richard, jun. The Park, Nottingham.
*Birks, Rev. Thomas Rawson. Trinity College, Cambridge.
1842. *Birley, Richard. Seedley, Pendleton, Manchester.
1861. ‡*Birley, Thomas Thorneley.*
1841. *Birt, William Radcliff, F.R.A.S. Cynthia-villa, Clarendon-road, Walthamstow, London, N.E.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1863. ‡Black, William. South Shields.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.
1859. ‡Blackie, John Stewart, Professor of Greek. Edinburgh.
1855. *Blackie, W. G., Ph.D., F.R.G.S. 1 Belhaven-terrace, Glasgow.
1870. §Blackmore, W. Founder's Court, Lothbury, London, E.C.
*Blackwall, Rev. John, F.L.S. Hendre House, near Llanrwst, Denbighshire.
1863. ‡Bladen, Charles. Jarrow Iron Company, Newcastle-on-Tyne.
1863. ‡Blake, C. Carter, Ph.D., F.G.S. 170 South Lambeth-road, London, S.W.
1849 *Blake, Henry Wollaston, M.A., F.R.S. 8 Devonshire-place, Portland-place, London, W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1845. ‡Blakesley, Rev. J. W., B.D. Ware Vicarage, Hertfordshire.
1861. §Blakiston, Matthew. Mobberley, Knutsford.
*Blakiston, Peyton, M.D., F.R.S. Warrior-square, St. Leonard's-on-Sea.
1868. ‡Blanc, Henry, M.D. 9 Bedford-street, Bedford-square, London, W.C.
1869. ‡Blandford, W. T., F.G.S., Geological Survey of India, Calcutta. (12 Keppel-street, Russell-square, London, W.C.)
Blanshard, William. Redcar.

Year of Election.

Blore, Edward, F.S.A. 4 Manchester-square, London, W.
1870. §Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Capt. Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1850. ‡Blyth, John, M.D., Professor of Chemistry in Queen's College, Cork.
1858. *Blythe, William. Holland Bank, near Accrington.
1870. §Boardman, Edward. Queen-street, Norwich.
Boase, C. W. Royal Bank, Dundee.
1845. ‡Bodmer, Rodolphe. Newport, Monmouthshire.
1864. ‡Bogg, J. Louth, Lincolnshire.
1866. §Bogg, Thomas Wemyss. Louth, Lincolnshire.
1859. *Bohn, Henry G., F.L.S., F.R.A.S., F.R.G.S. North End House, Twickenham, London, S.W.
1859. ‡Bolster, Rev. Prebendary John A. Cork.
Bolton, R. L. Laurel Mount, Aigburth-road, Liverpool.
1849. ‡Bolton, Thomas. Hyde House, near Stourbridge.
1866. ‡Bond, Banks. Low Pavement, Nottingham.
1863. ‡Bond, Francis T., M.D. Hartley Institution, Southampton.
Bond, Henry John Hayes, M.D. Cambridge.
Bonomi, Ignatius. 36 Blandford-square, London, N.W.
Bonomi, Joseph. Soane's Museum, 15 Lincoln's-Inn-fields, London, W.C.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. §Booth, James. Castlemere, Rochdale.
1835. ‡Booth, Rev. James, LL.D., F.R.S., F.R.A.S. The Vicarage, Stone, near Aylesbury.
1861. *Booth, John. Greenbank, Monton, near Manchester.
1861. *Booth, William. Holybank, Cornbrook, Manchester.
1861. *Borchardt, Dr. Louis. Oxford Chambers, Oxford-street, Manchester.
1849. ‡Boreham, William W., F.R.A.S. The Mount, Haverhill, Newmarket.
1863. ‡Borries, Theodore. Lovaine-crescent, Newcastle-on-Tyne.
*Bossey, Francis, M.D. Oxford-road, Red Hill, Surrey.
Bosworth, Rev. Joseph, LL.D., F.R.S., F.S.A., M.R.I.A., Professor of Anglo-Saxon in the University of Oxford. Oxford.
1867. §Botly, William, F.S.A. Salisbury Villa, Hamlet-road, Upper Norwood, London, S.E.
1858. ‡Botterill, John. Burley, near Leeds.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
Bottomley, William. Forbreda, Belfast.
1850. ‡Bouch, Thomas, C.E. 1 South Hanover-street, Edinburgh.
1870. §Boult, Swinton. 1 Dale-street, Liverpool.
Bourne, Lieut.-Colonel J. D.
1866. §Bourne, Stephen. Abberley Lodge, Hudstone-drive, Harrow, N.W.
1858. ‡Bousfield, Charles. Roundhay, near Leeds.
1868. ‡Boulton, W. S. Norwich.
1870. §Bower, Anthony. Bowerdale, Seaforth, Liverpool.
1867. ‡Bower, Dr. John. Perth.
1846. *Bowerbank, James Scott, LL.D., F.R.S., F.G.S., F.L.S., F.R.A.S. 2 East Ascent, St. Leonard's-on-Sea.
1856. *Bowlby, Miss F. E. 27 Lansdown-crescent, Cheltenham.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
Bowman, William, F.R.S. 5 Clifford-street, London, W.
1869. §Bowring, Charles T. Elmsleigh, Princes' Park, Liverpool.
‡Bowring, Sir John, LL.D., F.R.S. Athenæum Club, Pall Mall, London, S.W.; and Claremont, Exeter.

Year of
Election.

1869. ‡Bowring, J. C. Larkbeare, Exeter.
1863. ‡Bowron, James. South Stockton-on-Tees.
1863. §Boyd, Edward Fenwick. Moor House, near Durham.
Boyle, Alexander, M.R.I.A. 35 College Green, Dublin.
1865. ‡Boyle, Rev. G. D. Soho House, Handsworth, Birmingham.
Brabant, R. H., M.D. Bath.
1869. *Braby, Frederick, F.G.S., F.C.S. Mount Henley, Sydenham Hill, S.E.
1870. §Brace, Edmund. 17 Water-street, Liverpool.
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1864. §Bradbury, Thomas. Longroyde, Brighouse.
1861. *Bradshaw, William. 35 Mosley-street, Manchester.
1842. *Brady, Sir Antonio, F.G.S. Maryland Point, Stratford, Essex.
1857. *Brady, Cheyne, M.R.I.A. Four Courts, Co. Dublin.
Brady, Daniel F., M.D. 5 Gardiner's Row, Dublin.
1863. ‡Brady, George S. 22 Fawcett-street, Sunderland.
1862. §Brady, Henry Bowman, F.L.S., F.G.S. 40 Mosley-street, Newcastle-on-Tyne.
1858. ‡Brae, Andrew Edmund. 29 Park-square, Leeds.
1864. §Braham, Philip. 6 George-street, Bath.
1870. §Braidwood, Dr. Delemere Terrace, Birkenhead.
1864. §Braikenridge, Rev. George Weare, M.A., F.L.S. Clevedon, Somerset.
1865. §Bramwell, Frederick J., C.E. 37 Great George-street, London, S.W.
Brancker, Rev. Thomas, M.A. Limington, Somerset.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Henry. 19 Finsbury-circus, London, E.C.
Brandreth, John Moss. Preston, Lancashire.
1852. ‡Brazier, James S. Professor of Chemistry in Marischal College and University of Aberdeen.
1857. ‡Brazill, Thomas. 12 Holles-street, Dublin.
1869. *Breadalbane, The Right Hon. Earl of. Taymouth Castle, N. B.; and Carlton Club, Pall Mall, London, S.W.
1859. ‡Brebner, Alexander C. Audit Office, Somerset House, London, W.C.
1859. *Brebner, James. Moss Villa, Elgin, N.B.
1867. ‡Brechin, The Right Rev. Alexander Penrose Forbes, Lord Bishop of, D.C.L. Castlehill, Dundee.
1868. §Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1869. ‡Brent, Colonel Robert. Woodbury, Exeter.
1860. ‡Brett, G. Salford.
1854. **Brett, Henry Watkins.*
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1865. §Brewin, William. Cirencester.
1867. §Bridgman, William Kenceley. 69 St. Giles's-street, Norwich.
1870. *Bridson, Joseph R. Belle Isle, Windermere.
1870. §Brierley, Joseph, C.E. Newmarket-street, Blackburn.
1866. *Briggs, Arthur, Hon. Sec. Phil. Soc., Bradford, Yorkshire.
*Briggs, General John, F.R.S., M.R.A.S., F.G.S. 2 Tenterden-street, London, W.
1870. *Brigg, John. Keighley, Yorkshire.
1866. §Briggs, Joseph. Ulverstone, Lancashire.
1863. *Bright, Sir Charles Tilston, C.E., F.G.S., F.R.G.S., F.R.A.S. 69 Lancaster Gate, W.; and 6 Westminster Chambers, Victoria-street, London, S.W.
1870. §Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
Bright, The Right Hon. John, M.P. Rochdale, Lancashire.

Year of Election.

1868. ‡Brine, Commander Lindesay. Army and Navy Club, Pall Mall, London, S.W.
1863. ‡*Brivit, Henri.*
1842. Broadbent, Thomas. Marsden-square, Manchester.
1859. ‡Brodhurst, Bernard Edwin. 20 Grosvenor-street, Grosvenor-square, London, W.
1847. ‡Brodie, Sir Benjamin C., Bart., M.A., F.R.S., Professor of Chemistry in the University of Oxford. Cowley House, Oxford.
1834. ‡Brodie, Rev. James. Monimail, Fifeshire.
1865. ‡Brodie, Rev. Peter Bellenger, M.A., F.G.S. Rowington Vicarage, near Warwick.
1853. ‡Bromby, J. H., M.A. The Charter House, Hull.
Bromilow, Henry G. Merton Bank, Southport, Lancashire.
*Brooke, Charles, M.A., F.R.S. 16 Fitzroy-square, London, W.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Drewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1863. §Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.
1846. *Brooks, Thomas. Cranshaw Hall, Rawstenstall, Manchester.
Brooks, William. Ordfall-hill, East Retford, Nottinghamshire.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
1863. *Brough, Lionel H., F.G.S., one of Her Majesty's Inspectors of Coal-Mines. 11 West Mall, Clifton, Bristol.
1867. §Brough, John Cargill. London Institution, Finsbury Circus, London, E.C.
*Broun, John Allan, F.R.S., Late Astronomer to His Highness the Rajah of Travancore.
1869. ‡Brown, Mrs. 1 Stratton-street, Piccadilly, London, W.
1863. ‡Brown, Alexander Crum, M.D., F.R.S.E., Professor of Chemistry in the University of Edinbugh. 8 Belgrave-crescent, Edinburgh.
Brown, Charles Edward.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 3 Mansfield-place, Glasgow.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1858. §Brown, Alderman Henry. Bradford.
1865. §Brown, Edwin, F.G.S. Burton-upon-Trent.
1870. §Brown, Horace T. The Bank, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1858. ‡*Brown, John. Barnsley.*
1870. §Brown, J. Campbell, D.Sc. Royal Infirmary School of Medicine, Liverpool.
1859. ‡Brown, John Crombie, LL.D., F.L.S. Haddington, Scotland.
1863. ‡Brown, John H. 29 Sandhill, Newcastle-on-Tyne.
1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1856. *Brown, Samuel, F.S.S., F.R.G.S. The Elms, 42 Larkhall Rise, Clapham, London, S.W.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Lower Hardwick, Chepstow.
*Brown, William. 11 Maiden-terrace, York-road, Upper Holloway, London, N.
1855. ‡Brown, William. 11 AlbanyPlace, Glasgow.
1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41 *a* New-street, Birmingham.
1863. ‡*Browne, B. Chapman. Tynemouth.*
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1865. *Browne, William. The Friary, Lichfield.

Year of Election.

1865. §Browning, John, F.R.A.S. 111 Minories, London, E.
1855. §Brownlee, James, Jun. 173 St. George's-road, Glasgow.
Brownlie, Archibald. Glasgow.
1853. ‡Brownlow, William B. Villa-place, Hull.
1852. ‡Bruce, Rev. William. Belfast.
1863. *Brunel, H. M. 18 Duke-street, Westminster, S.W.
1863. ‡Brunel, J. 18 Duke-street, Westminster, S.W.
1868. ‡Brunton, T. L. Eastfield, St. Boswell's, Edinburgh.
1859. ‡*Bryant, Arthur C.*
1861. ‡Bryce, James. York Place, Higher Broughton, Manchester.
Bryce, James, M.A., LL.D., F.R.S.E., F.G.S. High School, Glasgow, and Bowes Hill, Blantyre, by Glargow.
Bryce, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.
1850. ‡Bryson, Alexander, F.R.S.E. Hawkhill, Edinburgh.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1867. §Buccleuch and Queensberry, His Grace the Duke of, K.G., D.C.L., F.R.S. L. & E., F.S.L. Whitehall Gardens, London, S.W.; and Dalkeith Palace, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
Buchanan, Andrew, M.D. Glasgow.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. Poulton cum Seacombe, Cheshire.
*Buck, George Watson. Ramsay, Isle of Man.
1864. §Buckle, Rev. George, M.A. Twerton Vicarage, Bath.
1865. *Buckley. Henry. 29 Calthorpe-street, Edgbaston, Birmingham.
1848. *Buckman, James, F.L.S., F.G.S. Bradford Abbas, Sherbourne, Dorsetshire.
1869. ‡Bucknill, J. Hillmorton Hall, Exeter.
1851. *Buckton, George Bowdler, F.R.S., F.L.S. Weycombe, Haslemere, Surrey.
1848. *Budd, James Palmer. Ystalyfera Iron Works, Swansea.
1845. *Bunbury, Sir Charles James Fox, Bart., F.R.S., F.L.S., F.G.S., F.R.G.S. Barton Hall, Bury St. Edmunds.
1845. ‡Bunbury, Edward H., M.A., F.G.S. 35 St. James's-street, London, S.W.
1865. ‡Bunce, John Mackray. 'Journal Office,' New-street, Birmingham.
Bunch, Rev. Robert James, B.D. Emanuel Rectory, Loughborough.
1863. §Bunning, T. Wood. 34 Grey-street, Newcastle-on-Tyne.
Bunt, Thomas G. Nugent-place, Bristol.
1842. *Burd, John. 37 Jewin-street, Aldersgate-street, London, E.C.
1869. ‡Burdett-Coutts, Miss. Stratton-street, Piccadilly, London, W.
Burgoyne, Sir John F., Bart., G.C.B., Field Marshal, D.C.L., F.R.S. 8 Gloucester-gardens, London, W.
1857. ‡Burk, J. Lardner, LL.D. 2 North Great George-street, Dublin.
1865. ‡Burke, Luke. 5 Albert-terrace, Acton, London, W.
1869. *Burnell, Arthur Coke. Sidmouth, South Devon.
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1860. ‡Burrows, Montague, M.A., Commander R.N. Oxford.
1866. *Burton, Frederick M. Highfield, Gainsborough.
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *Busk, George, F.R.S., V.P. L.S., F.G.S., Examiner in Comparative Anatomy in the University of London. 32 Harley-street, Cavendish-square, London, W.
1857. ‡Butt, Isaac, Q.C. 4 Henrietta-street, Dublin.
1855. *Buttery, Alexander W. Monkland Iron and Steel Company, Cardarroch, near Airdrie.

Year of Election.

1870. §Buxton, David, Principal of the Liverpool Deaf and Dumb Institution, Oxford-street, Liverpool.
Buxton, Edward North.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1854. ‡Byerley, Isaac, F.L.S. Seacombe, Liverpool.
Byng, William Bateman. Orwell Works House, Ipswich.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh, Armagh.

Cabbell, Benjamin Bond, M.A., F.R.S., F.S.A., F.R.G.S. 1 Brick-court, Temple, E.C.; and 52 Portland-place, London, W.
1858. §Cail, John. Stokesley, Yorkshire.
1863. ‡Cail, Richard. The Fell, Gateshead.
1854. §Caine, Nathaniel. Broughton Hall, Broughton-in-Furness.
1858. *Caine, Rev. William, M.A. Ducie-grove, Oxford-road, Manchester.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1861. *Caird, James Key. Finnart on Loch Long, by Helensburgh, Glasgow.
1855. *Caird, James T. Greenock.
1857. ‡Cairnes, Professor. Queen's College, Galway.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1842. Callender, W. R. The Elms, Didsbury, Manchester.
1853. ‡Calver, E. K., R.N. 21 Norfolk-street, Sunderland.
1857. ‡Cameron, Charles A., M.D. 17 Ely-place, Dublin.
1870. §Cameron, John, M.D. 17 Rodney-street, Liverpool.
1859. ‡Campbell, Rev. C. P., Principal of King's College, Aberdeen.
1857. *Campbell, Dugald, F.C.S. 7 Quality-court, Chancery-lane, London, E.C.
1855. ‡Campbell, Dugald, M.D. 186 Sauchiehall-street, Glasgow.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
*Campbell, Sir James. 29 Ingram-street, Glasgow.
Campbell, John Archibald, F.R.S.E. Albyn-place, Edinburgh.
1852. ‡*Campbell, William. Donegal-Square West, Belfast.*
1859. ‡Campbell, William. Dunmore, Argyllshire.
1862. *Campion, Rev. William M. Queen's College, Cambridge.
1853. ‡Camps, William, M.D., F.L.S., F.R.G.S. 84 Park-street, Grosvenor-square, London, W.
1868. *Cann, William. 9 Southernhay, Exeter.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
Carlisle, Harvey Goodwin, D.D., Lord Bishop of. Carlisle.
1861. ‡Carlton, James. Mosley-street, Manchester.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. §Carmichael, George. 11 Dudhope-terrace, Dundee.
Carmichael, H. 18 Hume-street, Dublin.
Carmichael, John T. C. Messrs. Todd & Co., Cork.
*Carpenter, Philip Pearsall, B.A., Ph.D. Montreal, Canada.
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1845. ‡Carpenter, William B., M.D., F.R.S., F.L.S., F.G.S., Registrar of the University of London. 56 Regent's Park Road, London, N.W.
1849. ‡Carr, William. Gomersal, Leeds.
1842. *Carr, William, M.D., F.L.S., F.R.C.S. Lee Grove, Blackheath, S.E.
1861. *Carrick, Thomas. 5 Clarence-street, Manchester.

Year of Election.

1867. §Carruthers, William, F.L.S., F.G.S. British Museum, London, W.C.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1857. ‡Carte, Alexander, M.D. Royal Dublin Society, Dublin.
1868. §Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1870. §Carter, Dr. William. 69 Elizabeth-street, Liverpool.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, C.E. Long Carr, Barnsley, Yorkshire.
*Cartmell, Rev. James, D.D., F.G.S., Master of Christ's College. Christ College Lodge, Cambridge.
Cartmell, Joseph, M.D. Carlisle.
1862. ‡Carulla, Facundo, F.A.S.L. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1870. §Cartwright, Joseph. 70 King-street, Dunkinfield.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. South Grove, Highgate, London, N.
1842. *Cassels, Rev. Andrew, M.A. Batley, near Leeds.
Castle, Charles. Clifton, Bristol.
1853. ‡Cator, John B., Commander R.N. 1 Adelaide-street, Hull.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1866. ‡Catton, Alfred R., M.A., F.R.S.E. Dundonnell House, Dingwall, N.B.
1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. ‡Cayley, Arthur, LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Mathematics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1870. §Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. 35 Park-square, Leeds.
1860. §Chadwick, David, M.P.
1842. Chadwick, Edwin, C.B. Richmond, Surrey.
1842. Chadwick, Elias, M.A. Pudleston-court, near Leominster.
1842. Chadwick, John. Broadfield, Rochdale.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1861. ‡Chadwick, Thomas. Wilmslow Grange, Cheshire.
*Challis, Rev. James, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy in the University of Cambridge. 13 Trumpington-street, Cambridge.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1865. ‡Chamberlain, J. H. Christ Church-buildings, Birmingham.
1868. ‡Chamberlin, Robert. Catton, Norwich.
1842. Chambers, George. High Green, Sheffield.
Chambers, John. Ridgefield, Manchester.
1868. ‡Chambers, W. O. Lowestoft, Suffolk.
*Champney, Henry Nelson. The Mount, York.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James Simmers. Handsworth, Birmingham.
1865. §Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A. Frewen Hall, Oxford.
1850. ‡Chapman, Prof. E. J. 4 Addison-terrace, Kensington, London, W.
1866. ‡Chapman, Ernest T., F.C.S. 21 London-villas, Devonport-road Shepherd's Bush, London, W.
1861. *Chapman, John. Hill End Mottram, Manchester.
1866. ‡Chapman, William. The Park, Nottingham.
1854. ‡*Chapple, Frederick.*
1836. Charlesworth, Edward, F.G.S. Whittington Club, Arundel-street, London, W.C.

Year of Election.

1863. ‡Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.
1863. ‡*Charlton, F.*
1866. ‡Charnock, Richard Stephen, Ph.D., F.S.A., F.R.G.S. 8 Gray's Inn-square, London, W.C.
Chatto, W. J. P. Union Club, Trafalgar-square, London, S.W.
1867. *Chatwood, Samuel. 2 Wentworth-place, Bolton.
1864. ‡Cheadle, W. B., M.A., M.D., F.R.G.S. 6 Hyde Park-place, Cumberland Gate, London, W.
1842. *Cheetham, David. 12 Camden-crescent, Bath.
1853. *Chesney, Major-General Francis Rawdon, R.A., D.C.L., F.R.S., F.R.G.S. Ballyardle, Newry, Kilkeel, Co. Down.
*Chevallier, Rev. Temple, B.D., F.R.A.S., Professor of Mathematics and Astronomy in the University of Durham. The College, Durham.
1865. §Child, Gilbert W., M.A., M.D., F.L.S. Elmhurst, Great Missenden, Bucks.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
Christison, Robert, M.D., D.C.L., F.R.S.E., Professor of Dietetics, Materia Medica, and Pharmacy in the University of Edinburgh. Edinburgh.
1870. §Church, A. H., F.C.S., Professor of Chemistry in the Royal Agricultural College, Cirencester.
1860. ‡Church, William Selby, M.A. 1 Harcourt Buildings, Temple, London, E.C.
1857. ‡Churchill, F., M.D. 15 Stephen's Green, Dublin.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1863. ‡Clapham, A. 3 Oxford-street, Newcastle-on-Tyne.
1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1855. §Clapham, Robert Calvert. Wincomblee, Walker, Newcastle-on-Tyne.
1858. ‡Clapham, Samuel. 17 Park-place, Leeds.
1869. §Clapp, Frederick. 44 Magdalen-street, Exeter.
1857. ‡Clarendon, Frederick Villiers. 11 Blessington-street, Dublin.
**Clark, Rev. Charles, M.A.*
Clark, Courtney K. Haugh End, Halifax.
1859. ‡Clark, David. Coupar Angus, Fifeshire.
Clark, G. T. Bombay; and Athenæum Club, London, S.W.
1846. *Clark, Henry, M.D. 4 Upper Moira-place, Southampton.
1861. ‡Clark, Latimer. 1 Victoria-street, Westminster, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
Clarke, George. Mosley-street, Manchester.
1861. *Clarke, J. H. 5 Shakespeare-street, Ardwick, Manchester.
1842. Clarke, Joseph. Waddington Glebe, Lincoln.
1851. ‡Clarke, Joshua, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856. *Clay, Lieut.-Col. William. Park-hill House, The Dingle, Liverpool.
1866. ‡Clayden, Rev. P. W. Clarendon-street, Nottingham.
1857. *Clayton, David Shaw. Norbury, Stockport, Cheshire.
1850. ‡Cleghorn, Hugh, M.D., F.L.S., late Conservator of Forests, Madras. Stravithy, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.

Year of Election.

1861. §Cleland, John, M.D., Professor of Anatomy and Physiology in Queen's College, Galway.
1857. ‡Clements, Henry. Dromin, Listowel, Ireland.
‡Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.
Clerke, Rev. C. C., D.D., Archdeacon of Oxford and Canon of Christ Church, Oxford. Milton Rectory, Abingdon, Berkshire.
1852. ‡Clibborn, Edward. Royal Irish Academy, Dublin.
1869. §Clifford, Willliam Kingdon. Trinity College, Cambridge.
1865. ‡Clift, John E., C.E. Redditch, Bromsgrove, near Birmingham.
1861. *Clifton, R. Bellamy, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1854. ‡Close, The Very Rev. Francis, M.A. Carlisle.
1866. §Close, Thomas, F.S.A. St. James's-street, Nottingham.
Clough, Rev. Alfred B., B.D. Brandeston, Northamptonshire.
1859. ‡Clouston, Rev. Charles. Sandwick, Orkney.
1861. *Clouston, Peter. 1 Park-terrace, Glasgow.
1863. §Clutterbuck, Thomas. Warkworth, Acklington.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
1855. *Coats, Thomas. Fergeslie House, Paisley.
Cobb, Edward. South Bank, Weston, near Bath.
1851. *Cobbold, John Chevallier, M.P. Holywells, Ipswich; and Athenæum Club, London, S.W.
1864. §Cobbold, T. Spencer, M.D., F.R.S., F.L.S., Lecturer on Zoology and Comparative Anatomy at the Middlesex Hospital. 84 Wimpole-street, Cavendish-square, London, W.
1854. ‡Cockey, William. 38 Burnbank Gardens, Glasgow.
1861. *Coe, Rev. Charles C. Seymour House, Seymour-street, Leicester.
1864. *Cochrane, James Henry. Woodside, Carrigrohane, Co. Cork.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1853. ‡Colchester, William, F.G.S. Grundesburgh Hall, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1859. ‡Cole, Edward. 11 Hyde Park-square, London, W.
1859. *Cole, Henry Warwick, Q.C. 2 Stone-buildings, Lincoln's Inn, London, W.C.
1860. ‡Coleman, J. J., F.C.S.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's Green, Dublin.
1861. *Collie, Alexander. 12 Kensington Palace Gardens, London, W.
1869. §Collier, F. W. Woodtown, Horrabridge, South Devon.
1861. ‡*Collinge, John.*
1854. ‡Collingwood, Cuthbert, M.A., M.B., F.L.S. Fair Mile, Henley-on-Thames.
1861. *Collingwood, J. Frederick, F.G.S. Anthropological Society, 4 St. Martin's-place, London, W.C.
1865. *Collins, James Tertius. Churchfield, Edgbaston, Birmingham.
Collis, Stephen Edward. Listowel, Ireland.
1868. *Colman, J. J., M.P. Carrow House, Norwich; and 105 Cannon-street, London, E.C.
1870. §Coltart, Robert. Devonshire-road, Prince's Park, Liverpool.
Colthurst, John. Clifton, Bristol.
1869. ‡*Colvill, W. H.*
1865. *Combe, Thomas, M.A. Clarendon Press, Oxford.
*Compton, The Rev. Lord Alwyn. Castle Ashby, Northamptonshire.
1846. *Compton, Lord William. 145 Piccadilly, London, W.

Year of
Election.

1852. ‡Connal, Michael. 16 Lynedock-terrace, Glasgow.
1858. ‡Conybeare, Henry. 20 Duke-street, Westminster, S.W.
1864. *Conwell, Eugene Alfred, M.R.I.A. Trim, Co. Meath, Ireland.
1859. ‡*Cook, E. R. Stamford-Hill, London, N.*
1861. **Cook, Henry.*
1863. ‡Cooke, Edward William, R.A., F.R.S., F.L.S., F.G.S. Glen Andred, Groombridge, Sussex; and Athenæum Club, Pall Mall, London, S.W.
1868. ‡Cooke, Rev. George H. The Parsonage, Thorpe, Norwich.
Cooke, James R., M.A. 73 Blessington-street, Dublin.
Cooke, J. B. Cavendish Road, Birkenhead.
1868. §Cooke, M. C. 2 Junction-villas, Upper Holloway, London, N.
Cooke, Rev. T. L., M.A. Magdalen College, Oxford.
Cooke, Sir William Fothergill. Telegraph Office, Lothbury, London, E.C.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, London, W.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1862. *Cookson, Rev. H. W., D.D. St. Peter's College Lodge, Cambridge.
1863. ‡Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.
1869. §Cooling, Edwin. Mile Ash, Derby.
1850. ‡Cooper, Sir Henry, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge Villas, Bayswater, London, W.
1868. ‡Cooper, W. J. 95 St. George's-road, Belgravia, London, S.W.
1846. ‡Cooper, William White. 19 Berkeley-square, London, W.
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1863. ‡Coppin, John. North Shields.
1842. *Corbet, Richard. Headington-hill, Oxford.
1842. Corbett, Edward. Ravenoak, Cheadle-hulme, Cheshire.
1855. ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology, Queen's College, Cork.
1870. *Corfield, W. H., M.A., M.B., Professor of Hygiène and Public Health in University College, London, W.C.
Cormack, John Rose, M.D., F.R.S.E. 5 Bedford-square, London, W.C.
1860. ‡*Corner, C. Tinsley.*
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazennose-street, Manchester.
Cotter, John.
1855. ‡Cotterill, Rev. Henry, Bishop of Grahamstown.
1864. §Cotton, General Frederick C. Athenæum Club, Pall Mall, London, S.W.
1869. ‡Cotton, William. Pennsylvania, Exeter.
*Cotton, Rev. William Charles, M.A. Vicarage, Frodsham, Cheshire.
1865. ‡Courtald, Samuel, F.R.A.S. 76 Lancaster Gate, London; and Gosfield Hall, Essex.
1834. ‡Cowan, Charles. Mount Grange, 29 Hope-terrace, Edinburgh.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
Cowie, Rev. Benjamin Morgan, M.A. 42 Upper Harley-street, Cavendish-square, London, W.
1860. ‡Cowper, Edward Alfred, M.I.C.E. 6 Great George-street, Westminster, London, S.W.
1867. *Cox, Edward. Clement Park, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park Lochee, Dundee.

Year of Election.

1870. *Cox, James. 8 Falkner-square, Liverpool.
1850. ‡Cox, John. Georgie Mills, Edinburgh.
Cox, Robert. 26 Rutland-street, Edinburgh.
1867. *Cox, Thomas Hunter. 1 Meadow-place, Dundee.
1866. §Cox, William. 50 Newhall-street, Birmingham.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1854. §Crace-Calvert, Frederick, Ph.D., F.R.S., F.C.S., Honorary Professor of Chemistry to the Manchester Royal Institution. Royal Institute, Manchester.
Craig, J. T. Gibson, F.R.S.E. Edinburgh.
1859. ‡Craig, S. Clayhill, Enfield, Middlesex.
1857. ‡Crampton, Rev. Josiah., M.R.I.A. The Rectory, Florence-court, Co. Fermanagh, Ireland.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1852. ‡Crawford, Alexander, jun. Mount Prospect, Belfast.
1857. ‡*Crawford, George Arthur, M.A.*
1870. *Crawshay, Mrs. Cyfartha Castle, Merthyr Tydvil.
Creyke, The Venerable Archdeacon. Beeford Rectory, Driffield.
*Crichton, William. 17 India-street, Glasgow.
1865. ‡Crocker, Edwin, F.C.S. 76 Hungerford Road, Holloway, London, N.
Croft, Rev. John, M.A., F.C.P.S.
1858. ‡Crofts, John. Hillary-place, Leeds.
Croker, Charles Phillips, M.D., M.R.I.A. 7 Merrion-square West, Dublin.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1855. ‡Crompton, Charles, M.A. 22 Hyde Park-square, London, W.
*Crompton, Rev. Joseph, M.A. Bracondale, Norwich.
1866. ‡Cronin, William. 4 Brunel-terrace, Nottingham.
Crook, William Henry, LL.D.
1870. §Crookes, Joseph. Brook Green, Hammersmith, London.
1865. §Crookes, William, F.R.S., F.C.S. 20 Mornington-road, Regent's Park, London, N.W.
1855. ‡Cropper, Rev. John. Wareham, Dosetshire.
1870. §Crosfield, C. J. 5 Alexander Drive, Princes Park, Liverpool.
1859. ‡Crosfield, John. Rothay Bank, Ambleside.
1870. *Crosfield, William, jun. 5 Alexander Drive, Prince's Park, Liverpool.
1870. §Crosfield, William, sen. Annesley, Aigburth, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1867. §Crosskey, Rev. H. W., F.G.S. 28 George Street, Edgbaston, Birmingham.
1853. ‡Crosskill, William, C.E. Beverley, Yorkshire.
1870. *Crossley, Edward. Park Road, Halifax.
1866. *Crossley, Louis J., F.M.S. Willow Hall, near Halifax.
1865. ‡Crotch, George Robert. 8 Pearl-street, Cambridge.
1861. §Crowley, Henry. Smedley New Hall, Cheetham, Manchester.
1863. §Crowther, Benjamin. Wakefield.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1860. ‡Cruickshank, John. City of Glasgow Bank, Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1859. ‡Crum, James. Busby. Glasgow.
1851. ‡Cull, Richard, F.R.S., F.R.G.S. 13 Tavistock-street, Bedford-square, London, W.C.
Culley, Robert. Bank of Ireland, Dublin.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1861. *Cunliffe, Edward Thomas. Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. Handforth, Manchester.

Year of
Election.

1850. ‡Cunningham, James, F.R.S.E. 50 Queen-street, Edinburgh.
1852. ‡Cunningham, John. Macedon, near Belfast.
1869. §Cunningham, Robert O., M.D. The Free Church Manse, Prestonpans, Scotland.
1850. ‡Cunningham, Rev. William, D.D. 17 Salisbury-road, Edinburgh.
1855. ‡Cunningham, William A. Manchester and Liverpool District Bank, Manchester.
1850. ‡Cunningham, Rev. W. B. Prestonpans, Scotland.
1866. ‡Cunnington, John. 68 Oakley-square, Bedford New Town, London, N.W.
1867. *Cursetjee, Manockjee, F.R.S.A., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡Curtis, Professor Arthur Hill, LL.D. 6 Trinity College, Dublin.
1866. ‡Cusins, Rev. F. L. 26 Addison-street, Nottingham.
1834. *Cuthbert, John Richmond. 40 Chapel-street, Liverpool.
Cuthbertson, Allan. Glasgow.

1863. ‡Daglish, John. Hetton, Durham.
1854. ‡Daglish, Robert, C.E. Orrell Cottage, near Wigan.
1863. ‡Dale, J. B. South Shields.
1853. ‡Dale, Rev. P. Steele, M.A. Hollingfare, Warrington.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, Dr. O. Newport, Dundee.
1867. ‡Dalgleish, W. Dundee.
1870. §Dallinger, Rev. W. H. Greenfield-road, Stoneycroft, Liverpool.
Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1850. ‡Dalmahoy, Patrick. 69 Queen-street, Edinburgh.
1859. ‡Dalrymple, Charles Elphinstone. West Hall, Aberdeenshire.
1859. ‡Dalrymple, Colonel. Troup, Scotland.
1867. *Dalrymple, Donald, M.D., M.P., F.R.G.S. Thorpe Lodge, Norwich.
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
*Dalton, Rev. James Edward, B.D. Seagrave, Loughborough.
1859. ‡*Daly, Lieut.-Colonel H. D.*
Dalziel, John, M.D. Holm of Drumlanrig, Thornhill, Dumfriesshire.
1862. ‡Danby, T. W. Downing Collge, Cambridge.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1847. ‡Danson, J. Towne. 12 Fitzclarence-street, Liverpool.
1849. *Danson, Joseph, F.C.S. 6 Shaw-street, Liverpool.
Danson, William. 6 Shaw-street, Liverpool.
1859. ‡Darbishire, Charles James. Rivington, near Chorley, Lancashire.
1861. *Darbishire, Robert Dukinfield, B.A., F.G.S. 26 George-street, Manchester.
1852. ‡*Darby, Rev. Jonathan L.*
Darwin, Charles R., M.A., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E., and M.R.I.A., Down, near Bromley, Kent.
1848. ‡Da Silva, Johnson. Burntwood, Wandsworth Common, London, S.W.
1859. ‡Daun, Robert, M.D., Deputy Inspector-General of Hospitals. The Priory, Aberdeen.
Davey, Richard, F.G.S. Redruth, Cornwall.
1870. §Davidson, Alexander, M.D. 8 Peel-street, Toxteth Park, Liverpool.
1859. ‡Davidson, Charles. Grove House, Auchmull, Aberdeen.
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1868. ‡Davie, Rev. W. C. Cringleford, Norwich.
1863. ‡Davies, Griffith. 17 Cloudesley-street, Islington, London, N.
1870. §Davies, Edward, F.C.S. Royal Institution, Liverpool.
Davies, John Birt, M.D. The Laurels, Edgbaston, Birmingham.
1842. Davies-Colley, Dr. Thomas. 40 Whitefriars, Chester

Year of Election.

1870. *Davis, A. S. Roundhay Vicarage, Leeds.
1864. §Davis, Charles E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1856. *Davis, Sir John Francis, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, Westbury by Bristol.
1859. ‡Davis, J. Barnard, M.D., F.R.S., F.S.A. Shelton, Staffordshire.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London, E.C.
1864. §Davison, Richard. Great Driffield, Yorkshire.
1857. ‡Davy, Edmund W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869 ‡Daw, R. M. Bedford-circus, Exeter.
1854. *Dawbarn, William. Elmswood, Aigburth, Liverpool.
1859. ‡*Dawes, Captain (Adjutant R.A. Highlanders).*
Dawes, John Samuel, F.G.S. Smethwick House, near Birmingham.
1860. *Dawes, John T., jun. Smethwick Hall, Smethwick, near Birmingham.
1864. ‡Dawkins, W. Boyd, M.A., F.R.S., F.G.S. Birchview, Norman-road, Rusholme, Manchester.
1865. ‡Dawson, George, M.A. Shenstone, Lichfield.
*Dawson, Henry. 14 St. James's-road, Liverpool.
1855. ‡Dawson, John W., M.A., LL.D., F.R.S., Principal of M'Gill College, Montreal, Canada.
Dawson, John. Barley House, Exeter.
1859. *Dawson, Captain William G. Plumstead Common-road, Kent, S.E.
1865. ‡*Day, Edward Charles H.*
1870. §Deacon, G. F. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1870. §Deacon, Henry Wade. Appleton House, near Warrington.
1859. ‡Dean, David. Banchory, Aberdeen.
1861. ‡Dean, Henry. Colne, Lancashire.
1854. §Deane, Henry, F.L.S. Clapham Common, London, S.W.
1870. *Deane, Rev. Dr. The Chestnuts, Moseley-road, Manchester.
*Deane, Sir Thomas. 26 Longford-terrace, Monkstown, Co. Dublin.
1866. ‡Debus, Heinrich, Ph.D., F.R.S., F.C.S. Lecturer on Chemistry at Guy's Hospital.
*De Grey and Ripon, George Frederick, Earl, D.C.L., F.R.S., F.L.S., F.R.G.S. 1 Carlton-gardens, London, S.W.
1854. *De La Rue, Warren, D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. Cranford, Middlesex; and Reform Club, London, S.W.
1870. §De Meshin, Thomas. 5 Fig Tree-court, Temple, London, E.C.
Denchar, John. Morningside, Edinburgh.
Denison, Sir William Thomas, K.C.B., Col. R.E., F.R.S., F.R.G.S., East Brent, Weston-super-Mare, Somerset.
*Dent, Joseph. Ribston Hall, Wetherby.
Dent, William Yerbury. Royal Arsenal, Woolwich, S.E.
1870. *Denton, J. Bailey. 22 Whitehall-place, London, S.W.
1856. *Derby, The Right Hon. The Earl of, LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
De Saumarez, Rev. Havilland, M.A. St. Peter's Rectory, Northampton.
1870. §Desmond, Dr. 44 Irvine-street, Edge Hill, Liverpool.
1868. §Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
De Tabley, George, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
1869. ‡Devon, The Right Hon. The Earl of. Powderham Castle, near Exeter.

Year of Election.

*Devonshire, William, Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. ‡Dewar, James. Chemical Laboratory, The University, Edinburgh.
1858. ‡Dibb, Thomas Townend. Little Woodhouse, Leeds.
1870. §Dickens, Colonel C. H. Lord-street, Liverpool.
1852. ‡Dickie, George, M.A., M.D., F.L.S., Professor of Botany in the University of Aberdeen.
1864. *Dickinson, F. H. Kingweston, Somerton, Taunton; and 119 St. George's-square, London, S.W.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1861. *Dickinson, William Leeson 1 St. James's-street, Manchester.
1867. §Dickson, Alexander, M.D., Professor of Botany in the University of Glasgow. The College, Glasgow.
1868. ‡Dickson, J. Thompson. 33 Harley-street, London, W.
1863. *Dickson, William, F.S.A., Clerk of the Peace for Northumberland. Alnwick, Northumberland.
1862. *Dilke, Sir Charles Wentworth, Bart., M.P. 76 Sloane-street, London, S.W.
1848. ‡Dillwyn, Lewis Llewelyn, M.P., F.L.S., F.G.S. Parkwern, near Swansea.
1869. §Dingle, Edward. 19 King Street, Tavistock.
1859. *Dingle, Rev. J. Lanchester Vicarage, Durham.
1837. Dircks, Henry, C.E., LL.D., F.C.S. 48 Charing Cross, London, S.W.
1868. ‡Dittmar, W. The University, Edinburgh.
1853. ‡Dixon, Edward, M.Inst.C.E. Wilton House, Southampton.
1865. ‡Dixon, L. Hooton, Cheshire.
1858. ‡*Dixon, Isaiah.*
1861. ‡Dixon, W. Hepworth, F.S.A., F.R.G.S. 6 St. James's Terrace, London, N.W.
1859. ‡*Dixon, William Smith.*
*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.
1851. ‡Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.
1860. *Dobbs, Archibald Edward, M.A. Richmond-road, Ealing, Middlesex.
1864. *Dobson, William. Oakwood, Bathwick-hill, Bath.
Dockray, Benjamin. Lancaster.
1870. *Dodd, John. 30 Canning-place, Liverpool.
1857. ‡Dodds, Thomas W., C.E. Rotherham.
*Dodsworth, Benjamin. Burton Croft, York.
*Dodsworth, George. Clifton-grove, near York.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡Domvile, William C., F.Z.S. Thorn-hill, Bray, Dublin.
1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
*Donisthorpe, George Edmund. Belvedere, Harrowgate, Yorkshire.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1861. ‡Donnelly, Captain, R.E. South Kensington Museum, London, W.
1857. *Donnelly, William, C.B., Registrar-General for Ireland. 5 Henrietta-street, Dublin.
1857. ‡Donovan, M., M.R.I.A. Clare-street, Dublin.
1863. ‡Doubleday, Thomas. 25 Ridley-place, Newcastle-upon-Tyne.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1863. *Doughty, C. Montagu. 5 Gloucester-place, Portman-square, London, W.

Year of Election.

1855. §Dove, Hector. Rose Cottage, Trinity, near Edinburgh.
1870. §Dowie, J. M. Walstones, West Kirby, Liverpool.
Downall, Rev. John. Okehampton, Devon.
1857. ‡ Downing, S., LL.D., Professor of Civil Engineering in the University of Dublin. Dublin.
1865. *Dowson, E. Theodore. Geldestone, near Beccles, Suffolk.
1869. ‡Drake, Francis, F.G.S. Teign House, Hinckley, Leicester.
Drennan, William, M.R.I.A. 35 North Cumberland-street, Dublin.
1868. §Dresser, Henry E. The Firs, South Norwood, Surrey.
1869. §Drew, Joseph, F.G.S. Weymouth.
1865. ‡Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.
Drummond, H. Home, F.R.S.E. Blair Drummond, Stirling.
1858. ‡Drummond, James. Greenock.
1859. ‡Drummond, Robert. 17 Stratton-street, London, W.
1866. *Dry, Thomas. 23 Gloucester-road, Regent's Park, London, N.W.
1863. ‡Dryden, James. South Benwell, Northumberland.
1856. *Ducie, Henry John Reynolds Moreton, Earl of, F.R.S. 1 Belgrave-square, London, S.W.; and Tortworth-court, Wotton-under-Edge.
1870. §Duckworth, Henry, F.L.S., F.G.S. 5 Cook-street, Liverpool.
1867. *Duff, Mounstuart Ephinstone Grant-, LL.B., M.P. 4 Queen's Gate-gardens, South Kensington, London, W.; and Eden, near Banff, Scotland.
1852. ‡Dufferin, The Rt. Hon. Lord. Highgate, London, N.; and Clandeboye, Belfast.
1859. *Duncan, Alexander. 7 Princes Gate, London.
1859. ‡Duncan, Charles. 52 Union-place, Aberdeen.
1866. *Duncan, James. 5 Highbury Hill, London, N.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1867. §Duncan, Peter Martin, M.D., F.R.S., Sec. G.S., Professor of Geology in King's College, London. 40 Blessington-road, Lee, S.E.
Dunlop, Alexander. Clober, Milngavie, near Glasgow.
1853. *Dunlop, William Henry. Annan-hill, Kilmarnock, Ayrshire.
1865. §Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1862. §Dunn, Robert, F.R.C.S. 31 Norfolk-street, Strand, London W.C.
Dunnington-Jefferson, Rev. Joseph, M.A., F.C.P.S. Thicket Hall, York.
1857. ‡Du Noyer, George V. 51 Stephen's Green, Dublin.
*Dunraven, Edwin, Earl of, F.R.S., F.R.A.S., F.G.S., F.R.G.S. Adare Manor, Co. Limerick; and Dunraven Castle, Glamorganshire.
1859. ‡*Duns, Rev. John, F.R.S.E.*
1852. ‡Dunville, William. Richmond Lodge, Belfast.
1866. ‡Duprey, Perry. Woodbury Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡Durham, Arthur Edward, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
Durnford, Rev. R. Middleton, Lancashire.
1857. ‡Dwyer, Henry L., M.A., M.B. 67 Upper Sackville-street, Dublin.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. §Dymond, Edward E. Oaklands, Aspland Guise, Woburn.
1870. §Dysdale, Dr. 36 A Rodney-street, Liverpool.

1868 ‡Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1864. ‡Earle, Rev. A. Rectory, Monkton Farleigh, Bath.

Year of Election.

Earle, Charles, F.G.S.
*Earnshaw, Rev. Samuel, M.A. Broomfield, Sheffield.
1863. §Easton, James. Nest House, near Gateshead, Durham
Eaton, Rev. George, M.A. The Pole, Northwich.
1870. §Eaton, Richard. Nottingham.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1867. ‡Eckersley, James. Leith Walk, Edinburgh.
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. North Laiths, Ollerton, Notts.
*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
*Edgeworth, Michael P., F.L.S., F.R.A.S. Mastrim House, Anerley, London, S.E.
1855. ‡Edmiston, Robert. Elmbank-crescent, Glasgow.
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 7 York-place, Northam, Southampton.
1867. *Edward, Allan. Farington Hall, Dundee.
1867. §Edward, Charles. Chambers, 8 Bank-street, Dundee.
1867. §Edward, James. Balruddery, Dundee.
Edwards, John. Halifax.
1855. *Edwards, J. Baker, Ph.D. Montreal, Canada.
1867. §Edwards, William. 70 Princes-street, Dundee.
1870. *Eddison, John Edwin. Park-square, Leeds.
*Egerton, Sir Philip de Malpas Grey, Bart., M.P., F.R.S., F.G.S. Oulton Park, Tarporley, Cheshire.
1859. *Eisdale. David A., M.A. 38 Dublin-street, Edinburgh.
1855. ‡Elder, David. 19 Paterson-street, Glasgow.
1858. ‡Elder, John. Elm Park, Govan-road, Glasgow.
1868. §Elger, Thomas Gwyn Empy. St. Mary, Bedford.
Ellacombe, Rev. H. T., F.S.A. Clyst, St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1855. §Elliot, Robert. Wolfelee, Hawick, N. B.
1861. *Elliot, Sir Walter, K.S.I., F.L.S. Wolfelee, Hawick, N. B.
1864. ‡Elliott, E. B. Washington, United States.
1862. §Elliott, Frederick Henry, M.A. 449 Strand, London, W.C.
Elliott, John Fogg. Elvet-hill, Durham.
1859. ‡Ellis, Henry S., F.R.A.S. Fair Park, Exeter.
1857. ‡Ellis, Hercules. Lisnaroc, Clones, Ireland.
1864. *Ellis, Alexander John, B.A., F.R.S. 25 Argyll-road, Kensington, London, W.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1864. §Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.
*Ellis, Rev. Robert, A.M. The Institute, St. Saviour's Gate, York.
1869. §Ellis, William Horton. Pennsylvania, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1862. ‡Elphinstone, H. W., M.A., F.L.S. Cadogan-place, London, S.W.
Eltoft, William. Care of J. Thompson, Esq., 30 New Cannon-street, Manchester.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1863. ‡Emery, Rev. W., B.D. Corpus Christi College, Cambridge.
1858. ‡Empson, Christopher. Headingley, near Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1866. ‡Enfield, William. Low Pavement, Nottingham.
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. §English, J. T. Wothorpe House, Stamford.

Year of Election.

Enniskillen, William Willoughby, Earl of, D.C.L., F.R.S., M.R.I.A., F.G.S. 26 Eaton-place, London, S.W.; and Florence Court, Fermanagh, Ireland.

1869. ‡Ensor, Thomas. St. Leonards, Exeter.

1869. *Enys, John Davis. Canterbury, New Zealand. (Care of J. S. Enys, Esq., Enys, Penryn, Cornwall.)

*Enys, John Samuel, F.G.S. Enys, Penryn, Cornwall.

1864. *Eskrigge, R. A., F.G.S. Batavia-buildings, Liverpool.

1862. *Esson, William, M.A., F.R.S., F.C.S. Merton College, Oxford.

Estcourt, Rev. W. J. B. Long Newton, Tetbury.

1869. ‡Etheridge, Robert, F.R.S.E., F.G.S., Palæontologist to the Geological Survey of Great Britain. Museum of Practical Geology, Jermyn-street; and 19 Halsey-street, Cadogan-place, London, S.W.

1870. *Evans, Arthur John. Nash Mills, Hemel Hempstead.

1865. *Evans, Rev. Charles, M.A. King Edward's School, Birmingham.

1849. *Evans, George Fabian, M.D. 14 Temple-row, Birmingham.

1848. ‡Evans, Griffith F. D., M.D. Trewern, near Welshpool, Montgomeryshire.

1869. *Evans, H. Saville W. Jorde Abbey, Chard.

1861. *Evans, John, F.R.S., F.S.A., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempstead.

1865. ‡Evans, Sebastian, M.A., LL.D. Highgate, near Birmingham.

1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.

1865. *Evans, William. Ellerslie, Augustus-road, Edgbaston, Birmingham.

Evanson, R. T., M.D. Holme Hurst, Torquay.

1868. *Everett, J. D., D.C.L., Professor of Natural Philosophy in Queen's College, Belfast. Rushmere Malone-road, Belfast.

1863. *Everitt, George Allen, K.L., K.H., F.R.G.S. Knowle Hall, Warwickshire.

1859. *Ewing, Archibald Orr. Ballikinrain, Killearn, by Glasgow.

1855. *Ewing, William. 209 West George-street, Glasgow.

1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, Knightsbridge, London; and Warren's, near Lyndhurst, Hants.

1866. ‡Eyre, Major-General Sir Vincent, F.R.G.S. Athenæum Club, Pall Mall, London, S.W.

Eyton, Charles. Hendred House, Abingdon.

1849. ‡Eyton, T. C. Eyton, near Wellington, Salop.

1842. Fairbairn, Thomas. Manchester.

*Fairbairn, Sir William, Bart., C.E., LL.D., F.R.S., F.G.S., F.R.G.S. Manchester.

1866. ‡*Fairbank, F. R., M.A.*

1865. ‡Fairley, Thomas. Chapel Allerton, Leeds.

1870. §Fairlie, Robert, C.E. Clapham Common, London, S.W.

1864. ‡Falkner, F. H. Lyncombe, Bath.

Fannin, John, M.A. 41 Grafton-street, Dublin.

1859. ‡Farquharson, Robert O. Houghton, Aberdeen.

1861. §Farr, William, M.D., D.C.L., F.R.S., Superintendent of the Statistical Department, General Registry Office. Southlands, Bickley, Kent.

1866. *Farrar, Rev. Frederick William, M.A., F.R.S. Marlborough.

1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.

1869. *Faulconer, R. S. Fairlawn, Clarence-road, Clapham Park, London.

1869. ‡Faulding, Joseph. 340 Euston-road, London, N.W.

1869. ‡Faulding, W. F. Didsbury College, Manchester.

1859. *Faulkner, Charles, F.S.A., F.G.S., F.R.G.S. Museum, Deddington, Oxon.

Year of
Election.

1859. *Fawcett, Henry, M.P., Professor of Political Economy in the University of Cambridge. 42 Bessborough-gardens, Pimlico, London, S.W.; and Trinity Hall, Cambridge.
1863. ‡Fawcus, George. Alma-place, North Shields.
1833. Fearon, John Peter. Cuckfield, Sussex.
1845. ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverston, Lancashire.
1864. §Fellowes, Frank P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square, and Keswick, near Belfast.
1855. ‡Ferguson, James. Gas Coal-works, Lesmahago, Glasgow.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1855. ‡*Ferguson, Peter.*
1867. §Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Samuel. 20 North Great George-street, Dublin.
1854. ‡Ferguson, William, F.L.S., F.G.S. 2 St. Aiden's-terrace, Birkenhead.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1863. *Fernie, John. 3 Moorland-terrace, Leeds.
1862. ‡Ferrers, Rev. N. M., M.A. Caius College, Cambridge.
1868. ‡Field, Edward. Norwich.
Field, Edwin W. 36 Lincoln's Inn Fields, London, W.C.
1869. *Field, Roger. 6 Cannon-row, Westminster, S.W.
Fielding, G. H., M.D. Tunbridge, Kent.
1864. ‡Finch, Frederick George, B.A., F.G.S. Fern House, Myrtle-place, Blackheath, London, S.E.
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1859. ‡Findlay, Alexander George, F.R.G.S. 53 Fleet-street, London, E.C.; Dulwich Wood Park, Surrey.
1863. ‡Finney, Samuel. Sheriff-hill Hall, Newcastle-upon-Tyne.
1868. ‡Firth, G. W. W. St. Giles's-street, Norwich.
Firth, Thomas. Northwick.
1851. *Fischer, William L. F., M.A., LL.D., F.R.S., Professor Mathematics in the University of St. Andrews, Scotland.
1858. ‡Fishbourne, Captain E. G., R.N. 6 Welamere-terrace, Paddington, London, W.
1869. ‡Fisher, Rev. Osmond, M.A., F.G.S. Harlston Rectory, near Cambridge.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1857. ‡Fitzgerald, The Right Hon. Lord Otho, M.P. 13 Dominick-street, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.
Fitzwilliam, Hon. George Wentworth, M.P., F.R.G.S. 19 Grosvenor-square, London, S.W.; and Wentworth House, Rotherham.
1865. ‡Fleetwood, D. J. 45 George Street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡Fleming, Professor Alexander, M.D. 20 Temple-row, Birmingham.
Fleming, Christopher, M.D. Merrion-square North, Dublin.
Fleming, John G., M.D. 155 Bath-street, Glasgow.
*Fleming, William, M.D. Rowton Grange, near Chester.
1867. §Fletcher, Alfred E. 21 Overton-street, Liverpool.
1870. §Fletcher, B. Edgington. Norwich.
1853. ‡Fletcher, Isaac, F.R.S., F.G.S., F.R.A.S. Tarn Bank, Workington.
1869. §Fletcher, Lavington E., C.E. 41 Cooperation-street, Manchester.
Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
Flood, Rev. James Charles.

Year of Election.

1862. ‡Flower, William Henry, F.R.S., F.L.S., F.G.S., F.R.C.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Royal College of Surgeons, Lincoln's Inn-fields, London, W.C.
1866. ‡Flowers, John W., F.G.S. Park Hill, Croydon, Surrey.
1867. ‡Foggie, William. Woodville, Maryfield, Dundee.
1854. *Forbes, David, F.R.S., F.G.S., F.C.S. 11 York-place, Portman-square, London, W.
Forbes, George, F.R.S.E.
1855. ‡Forbes, Rev. John. Symington Manse, Biggar, Scotland.
1855. ‡Forbes, Rev. John, D.D. 150 West Regent-street, Glasgow.
Ford, H. R. Morecombe Lodge, Yealand Congers, Lancashire.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park Gardens East, London, W.
*Forrest, William Hutton. The Terrace, Stirling.
1867. §Forster, Anthony. Newsham Grange, Winston, Darlington.
1849. *Forster, Thomas Emerson. 7 Ellison-place, Newcastle-upon-Tyne.
*Forster, William. Ballynure, Clones, Ireland.
1858. ‡Forster, William Edward. Burley, Otley, near Leeds.
1854. *Fort, Richard. 24 Queen's Gate-gardens, London, W.; and Read Hall, Whalley, Lancashire.
1870. §Forwood, William B. Hopeton House, Seaforth, Liverpool.
1865. ‡Foster, Balthazar W., M.D. 4 Old Square, Birmingham.
1865. *Foster, Clement Le Neve, D.Sc., F.G.S. East Hill, Wandsworth, London, S.W.
1857. *Foster, George C., B.A., F.R.S., F.C.S., Professor of Experimental Physics in University College, London, W.C. 16 King Henry's-road, London, N.W.
*Foster, Rev. John, M.A. The Oaks Parsonage, Loughborough.
1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1859. *Foster, Michael, M.D., F.L.S. Trinity College, Cambridge.
1859. §Foster, Peter Le Neve, M.A. Society of Arts, Adelphi, London, W.C.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1859. *Foster, S. Lloyd. Old Park Hall, Walsall, Staffordshire.
1842. Fothergill, Benjamin. 10 The Grove, Boltons, West Brompton, London.
1870. §Foulger, Edward. 55 Kirkdale-road, Liverpool.
1866. §Fowler, George. 56 Clarendon Street, Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1856. ‡Fowler, Rev. Hugh, M.A. College-gardens, Gloucester.
1870. *Fowler, Robert Nicholas, M.A., M.P., F.R.G.S. 36 Cavendish-square, London, W.
Fox, Alfred. Penjerrick, Falmouth.
1868. ‡Fox, Colonel A. Lane, F.G.S., F.S.A. 10 Upper Phillimore-gardens, Kensington, London, S.W.
1842. *Fox, Charles. Trebah, Falmouth.
*Fox, Rev. Edward, M.A. The Vicarage, Romford, Essex.
*Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.
Fox, Robert Were, F.R.S. Falmouth.
1866. *Francis, G. B. 8 Nelson-terrace, Stoke Newington, London, N.
1848. ‡Francis, George Grant, F.S.A. Burrows Lodge, Swansea.
Francis, William, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and 1 Matson Villas, Marsh-gate, Richmond, Surrey.
1846. ‡Frankland, Edward, D.C.L., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. 14 Lancaster Gate, London, W.

Year of Election.

*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
Franks, Rev. J. C., M.A. Whittlesea, near Peterborough.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James. 25 Westland-row, Dublin.
Fraser, James William. 8A Kensington Palace-gardens, London, W.
1865. *Fraser, John, M.A., M.D. Chapel Ash, Wolverhampton.
1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester, Sussex.
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
1869. §Frere, Sir Bartle, F.R.G.S. 22 Princes-gardens, London.
1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.
Frere, George Edward, F.R.S. Royden Hall, Diss, Norfolk.
1856. *Frerichs, John Andrew. 1 Keynsham Bank, Cheltenham.
Fripp, George D., M.D. Barnfield Hill, Southampton.
1857. *Frith, Richard Hastings, C.E. 48 Summer Hill, Dublin.
1863. *Frith, William. Burley Wood, near Leeds.
1869. ‡Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.
Frost, Charles, F.S.A. Hull.
1847. ‡Frost, William, F.R.A.S. Wentworth Lodge, Upper Tulse-hill, London, S.W.
1860. *Froude, William, C.E., F.R.S. Chelston Cross, Torquay.
Fry, Francis. Cotham, Bristol.
Fry, Richard. Cotham Lawn, Bristol.
Fry, Robert. Tockington, Gloucestershire.
1863. ‡Fryar, Mark. Eaton Moor Colliery, Newcastle-on-Tyne.
1859. ‡Fuller, Frederick, M.A., Professor of Mathematics in University and King's College, Aberdeen.
1869. §Fuller, George, C.E., Professor of Engineering in University College, London. Argyll-road, Kensington, London, W.
1852. ‡Furguson, Professor John C., M.A., M.B. Queen's College, Belfast.
Furlong, Rev. Thomas, M.A. 10 Sydney-place, Bath.
1864. *Furneaux, Rev. Alan. St. Germain's Parsonage, Cornwall.

*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡Gages, Alphonse, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Handsworth Grange, near Sheffield.
1850. ‡Gairdner, W. F., M.D. 18 Hill-street, Edinburgh.
1861. ‡Galbraith, Andrew. Glasgow.
Galbraith, Rev. J. A., M.R.I.A. Trinity College, Dublin.
1867. ‡Gale, James M. 33 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 338 Oxford-street, London, W.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1859. ‡*Galloway, James. Calcutta.*
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
Galloway, S. H. Linbach, Austria.
1860. *Galton, Captain Douglas, C.B., R.E., F.R.S., F.L.S., F.G.S., F.R.G.S. 12 Chester-street, Grosvenor-place, London, S.W.
1860. *Galton, Francis, F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. §Galton, John C., M.A., F.L.S. 13 Margaret-street, Cavendish-square, London, W.
1870. §Gamble, D. St. Helens, Lancashire.
1870. §Gamble, J. C. St. Helens, Lancashire.
1868. ‡Gamgee, Arthur, M.D. 27 Alva-street, Edinburgh.

Year of
Election.

1862. §Garner, Robert, F.L.S. Stoke-upon-Trent.
1865. §Garner, Mrs. Robert. Stoke-upon-Trent.
1842. Garnett, Jeremiah. Warren-street, Manchester.
1870. §Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Woolton Wood, Liverpool.
1847. *Gaskell, Samuel. Windham Club, St. James's-square, London, S.W.
1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
1846. §Gassiot, John Peter, D.C.L., F.R.S., F.C.S. Clapham Common, London, S.W.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East Grinsted, Sussex.
1859. ‡Geddes, William D., M.A., Professor of Greek, King's College, Old Aberdeen.
1854. ‡Gee, Robert, M.D. Abercromby-square, Liverpool.
1870. §Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. §Geikie, Archibald, F.R.S., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh.
1855. ‡Gemmell, Andrew. 38 Queen-street, Glasgow.
1855. ‡*Gemmell, Thomas.*
1854. §Gerard, Henry. 18A Rumford-place, Liverpool.
1870. §Gerstl, R. University College, London, W.C.
1856. *Gething, George Barkley. Springfield, Newport, Monmouthshire.
Gibb, Duncan. Strand-street, Liverpool.
1863. *Gibb, Sir George Duncan, Bart., M.D., M.A., LL.D., F.G.S. 1 Bryanston-street, London, W.; and Falkland, Fife.
Gibbins, Joseph.
Gibbins, Thomas.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1868. ‡Gibson, C. M. Bethel-street, Norwich.
Gibson, Edward. Hull.
*Gibson, George Stacey. Saffron Walden, Essex.
1852. ‡Gibson, James. 35 Mountjoy-square, Dublin.
1870. §Gibson, R. E. Sankey Mills, Earlestown, near Newton-le-Willows.
1859. ‡Gibson, William Sidney, M.A., F.S.A., F.G.S. Tynemouth.
1870. §Gibson, Thomas. 51 Oxford-street, Liverpool.
1870. §Gibson, Thomas, jun. 19 Parkfield-road, Princes Park, Liverpool.
1867. ‡Gibson, W. L., M.D. Tay-street, Dundee.
1849. ‡Gifford, Rev. E. H. Birmingham.
1842. Gilbert, Joseph Henry, Ph.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Blackrock, Dublin.
1859. *Gilchrist, James, M.D. Crichton Royal Institution, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex.
Giles, Rev. William. Netherleigh House, near Chester.
1868. ‡Gill, Joseph. Palermo, Scilly (care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.).
1864. ‡Gill, Thomas. 4 Sydney-place, Bath.
1850. ‡*Gillespie, Alexander, M.D. Edinburgh.*
1861. *Gilroy, George. Hindley House, Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1867. §Ginsburg, Rev. C. D., LL.D. Binfield, Bracknell, Berkshire.
1869. ‡Girdlestone, Rev. Canon E., M.A. Halberton Vicarage, Tiverton.
1850. *Gladstone, George, F.C.S., F.R.G.S. Care of Henry Strut, Esq., Clapham Common, London, S.W.
1849. *Gladstone, John Hall, Ph.D., F.R.S., F.C.S. 17 Pembridge-square, Hyde Park, London, W.
1861. *Gladstone, Murray. Broughton House, Manchester.

Year of
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1852. ‡*Gladstone, Thomas Murray.*
1861. *Glaisher, James, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath Kent.
1853. ‡Gleadon, Thomas Ward. Moira-buildings, Hull.
1870. §Glen, David C. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart. 6 Stone-buildings, Lincoln's Inn, London, W.C.
1867. ‡Gloag, John A. L. Inverleith-row, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1870. §Glynn, Thomas R. 1 Rodney-street, Liverpool.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1846. ‡Godwin-Austen, Robert A.C., B.A., F.R.S., F.G.S. Chilworth Manor, Guildford.
Goldsmid, Sir Francis Henry, Bart., M.P. St. John's Lodge, Regent's Park, London, N.W.
1842. *Gouch, Thomas L. Team Lodge, Saltwell, Gateshead.*
1857. ‡Good, John. 50 City Quay, Dublin.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1870. §Goodison, George William, C.E. Gateacre, Liverpool.
1842. *Goodman, John, M.D. Leicester-street, Southport.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. §Goodman, Neville. Peterhouse, Cambridge.
1868. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Westhall Vicarage, Wangford.
1859. ‡*Gordon, H. G.*
1870. §Gordon, Rev. Alexander. 49 Upper Parliament-street, Liverpool.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1865. ‡Gore, George, F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1870. §Gossage, William. Winwood, Woolton, Liverpool.
*Gotch, Rev. Frederick William, LL.D. Stokes Croft, Bristol.
*Gotch, Thomas Henry. Kettering.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, The Hon. G. S. Rathronan House, Clonmel.
1868. §Gould, Rev. George. Unthank-road, Norwich.
Gould, John, F.R.S., F.L.S., F.R.G.S., F.Z.S. 26 Charlotte-street, Bedford-square, London, W.C.
1854. ‡Gourlay, Daniel De la C., M.D. Tollington Park, Hornsey-road, London, N.
1867. ‡Gourley, Henry (Engineer). Dundee.
Gowland, James. London-wall, London, E.C.
1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *Graham, Cyril, F.L.S., F.R.G.S. 9 Cleveland-row, St. James's, London, S.W.
Graham, Lieutenant David. Mecklewood, Stirlingshire.
1870. §Graham, R. Hills. 4 Bentley-road, Princes Park, Liverpool.
1852. **Grainger, John.*
Grainger, Richard.
1870. §Grant, Colonel J. A., C.B., F.L.S., F.R.G.S. 7 Park-square West, London, N.W.
1859. ‡Grant, Hon. James. Cluny Cottage, Forres.
1855. *Grant, Robert, M.A., LL.D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.
1854. ‡Grantham, Richard B., C.E., F.G.S. 22 Whitehall-place, London, S.W.
Granville, Augustus Bozzi, M.D., F.R.S., M.R.I.A. 5 Cornwall-terrace, Warwick-square, Pimlico, London, S.W.
*Graves, Rev. Richard Hastings, D.D. Brigown Glebe House, Michelstown, Co. Cork.

Year of Election.

1870. §Gray, C. B. 5 Rumford-place, Liverpool.
1864. *Gray, Rev. Charles. The Vicarage, East Retford.
1865. ‡Gray, Charles. Swan-bank, Bilston.
1857. ‡Gray, Sir John, M.D. Rathgar, Dublin.
Gray, John.
*Gray, John Edward, Ph.D., F.R.S., Keeper of the Zoological Collections of the British Museum. British Museum, London, W.C.
1864. ‡Gray, Jonathan. Summerhill-house, Bath.
1859. ‡Gray, Rev. J. H. Bolsover Castle, Derbyshire.
1870. §Gray, T. Macfarlane. 12 Montenotte, Cork.
*Gray, William, F.G.S. Minster Yard, York.
1861. *Gray, Lt.-Colonel William, M.P. 26 Princes's-gardens, London, W.
1854. *Grazebrook, Henry, jun. Clent Grove, near Stourbidge, Worcestershire.
1866. §Greaves, Charles Augustus, M.B., LL.B. 13 Wardwick, Derby.
1869. §Greaves, William. Wellington-circus, Nottingham.
Green, Rev. Henry, M.A. Heathfield, Knutsford, Cheshire.
*Greenaway, Edward. 91 Lansdowne-road, Notting Hill, London, W.
1858. *Greenhalgh, Thomas. Sharples, near Bolton-le-Moors.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1862. *Greenwood, Henry. 32 Castle-street, and 37 Falkner-square, Liverpool.
1849. ‡Greenwood, William. Stones, Todmorden.
1861. *Greg, Robert Philips, F.G.S., F.R.A.S. Outwood Lodge, Prestwich, Manchester.
Gregg, T. H. 22 Ironmonger-lane, Cheapside, London, E.C.
1860. ‡Gregor, Rev. Walter, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Charles Hutton, C.E. 1 Delahay-street, Westminster, S.W.
1861. §Gregson, Samuel Leigh. Aigburth-road, Liverpool.
Gresham, Thomas M. Raheny, Dublin.
*Greswell, Rev. Richard, B.D., F.R.S., F.R.G.S. 39 St. Giles's-street, Oxford.
Grey, Captain The Hon. Frederick William. Howick, Northumberland.
1869. ‡Grey, Sir George, F.R.G.S. Belgrave-mansions, Grosvenor-gardens, London, S.W.
1866. ‡Grey, Rev. William Hewett C. North Sherwood, Nottingham.
1863. ‡Grey, W. S. Norton, Stockton-on-Tees.
1859. ‡Grierson, Thomas Boyle, M.D. Thornhill, Dumfriesshire.
1870. §Grieve, John, M.D. 21 Lynedock-street, Glasgow.
*Griffin, John Joseph, F.C.S. 22 Garrick-street, London, W.C.
Griffith, Rev. C. T., D.D. Elm, near Frome, Somerset.
1859. *Griffith, George, M.A., F.C.S. (ASSISTANT GENERAL SECRETARY.) Harrow.
Griffith, George R. Fitzwilliam-place, Dublin.
1868. ‡Griffith, Rev. John, M.A. The College, Brighton.
1870. §Griffith, N. R. The Coppa, Mold, North Wales.
1870. §Griffith, Rev. Professor. Bowden, Cheshire.
*Griffith, Sir Richard John, Bart., LL.D., F.R.S.E., M.R.I.A., F.G.S. 2 Fitzwilliam-place, Dublin.
1847. ‡Griffith, Thomas. Bradford-street, Birmingham.
Griffith, Walter H., M.A.
Griffiths, Rev. John, M.A. 63 St. Giles's, Oxford.
1870. §Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.

Year of
lection.

1864. ‡Groom-Napier, Charles Ottley, F.G.S. 20 Maryland-road, Harrow-road, London, N.W.
1869. §Grote, Arthur. Cambridge-terrace, Regent's Park, London, N.W.
Grove, William Robert, Q.C., M.A., Ph.D., F.R.S. 115 Harley-street, W; and 5 Crown Office-row, Temple, London, E.C.
1863. *Groves, Thomas B., F.C.S. 80 St. Mary's-street, Weymouth, Dorset.
1869. ‡Grubb, Howard. Rathmines, Dublin.
1857. ‡Grubb, Thomas, F.R.S., M.R.I.A. 141 Leinster-road, Dublin.
Guest, Edwin, LL.D., M.A., F.R.S., F.L.S., F.R.A.S., Master of Caius College, Cambridge. Caius Lodge, Cambridge; and Sandford-park, Oxfordshire.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College Green, Dublin.
1842. Guinness, Richard Seymour. 17 College Green, Dublin.
1856. *Guise, Sir William Vernon, Bart., F.G.S., F.L.S. Elmore-court, near Gloucester.
1862. ‡Gunn, Rev. John, M.A., F.G.S. Irstedd Rectory, Norwich.
1866. §Günther, Albert C. L. G., M.D., F.R.S. British Museum, London, W.C.
1868. *Gurney, John. Earlham Hall, Norwich.
1860. *Gurney, Samuel, M.P., F.L.S., F.R.G.S. 20 Hanover-terrace, Regent's Park, London, N.W.
*Gutch, John James. Blake-street, York.
1859. ‡*Guthrie, Frederick.*
1864. §Guyon, George. South Cliff Cottage, Ventnor, Isle of Wight.
1870. §Guyton, Joseph. 3 Derwent-road, Stoneycroft, Liverpool.
1857. ‡Gwynne, Rev. John. Tullyaguish, Letterkenny, Strabane, Ireland.

Hackett, Michael. Brooklawn, Chapelizod, Dublin.
1865. §Hackney, William. Siemens-Steel Works, Landore, Swansea.
1865. ‡Haden, W. H. Cawney Bank Cottage, Dudley.
1866. *Hadden, Frederick J. The Park, Nottingham.
1862. ‡Haddon, Frederick William. 12 St. James's-square, London, S.W.
1866. ‡Haddon, Henry. Lenton Field, Nottingham.
Haden, G. N. Trowbridge, Wiltshire.
1842. Hadfield, George. Victoria-park, Manchester.
1870. §Hadivan, Isaac. 3 Huskisson-street, Liverpool.
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. §Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Horton Hall, Bradford, Yorkshire.
1869. ‡Hake, R. C. Grasmere Lodge, Addison-road, Kensington, London, W.
1870. §Halhead, W. B. 7 Parkfield-road, Liverpool.
Halifax, The Right Hon. Viscount. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1854. *Hall, Hugh Fergie. Greenheys, Wallasey, Birkenhead.
1859. ‡Hall, John Frederic. Ellerker House, Richmond, Surrey.
Hall, John R. Sutton, Surrey.
1863. ‡Hall, Thomas Y. Eldon-square, Newcastle-on-Tyne.
*Hall, Thomas B. Australia (care of J. P. Hall, Esq., Crane House, Great Yarmouth).
1866. *Hall, Townshend M., F.G.S. Pilton, Barnstaple.
1860. §Hall, Walter. 10 Pier-road, Erith.
1868. *Hallett, William Henry, F.L.S. The Manor House, Kemp Town, Brighton.
1861. ‡Halliday, James. Whalley Court, Whalley Range, Manchester.
1857. ‡Halpin, George, C.E. Rathgar, near Dublin.

Year of Election.

Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
Halswell, Edmund S., M.A.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. 96 London-road, Leicester.
1866. §Hamilton, Archibald, F.G.S. South Barrow, Bromley, Kent.
1857. ‡Hamilton, Charles W. 40 Dominick-street, Dublin.
1865. §Hamilton, Gilbert. Leicester House, Kenilworth Road, Leamington.
Hamilton, The Very Rev. Henry Parr, Dean of Salisbury, M.A., F.R.S. L. & E., F.G.S., F.R.A.S. Salisbury.
1869. ‡Hamilton, John, F.G.S. Fyne Court, Bridgewater.
1840. *Hamilton, Mathie, M.D. 22 Warwick-street, Lauriston, Glasgow.
1869. §Hamilton, Roland. Oriental Club, Hanover-square, London, W.
1864. ‡*Hamilton, Rev. S. R., M.A. Hinton Lodge, Bournemouth.*
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1863. ‡Hancock, Albany, F.L.S. 4 St. Mary's-terrace, Newcastle-upon-Tyne.
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John. Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walker. 10 Upper Chadwell-street, Pentonville, London.
1857. ‡Hancock, William J. 74 Lower Gardiner-street, Dublin.
1847. ‡Hancock, W. Nelson, LL.D. 74 Lower Gardiner-street, Dublin.
1865. ‡Hands, M. Coventry.
Handyside, P. D., M.D., F.R.S.E. 11 Hope-street, Edinburgh.
1867. ‡Hannah, Rev. John, D.C.L. Trinity College, Glenalmond.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.
*Harcourt, A. G. Vernon, M.A., F.R.S., F.C.S. Christ Church, Oxford.
Harcourt, Rev. C. G. Vernon, M.A. Rothbury, Northumberland.
Harcourt, Egerton V. Vernon, M.A., F.G.S. Whitwell Hall, Yorkshire.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Hill's Court, Exeter.
1869. ‡Harding, William D. Kings Lynn, Norfolk.
1864. §Hardwicke, Robert, F.L.S. 192 Piccadilly, London, W.
*Hare, Charles John, M.D., Professor of Clinical Medicine in University College, London. 57 Brook-street, Grosvenor-square, London, W.
Harford, Summers. Haverfordwest.
1858. ‡Hargrave, James. Burley, near Leeds.
1853. §Harkness, Robert, F.R.S. L. & E., F.G.S., Professor of Geology in Queen's College, Cork.
Harkworth, Timothy. Soho Shilden, Darlington.
1862. *Harley, George, M.D., F.R.S., Professor of Medical Jurisprudence in University College, London. 25 Harley-street, London, W.
*Harley, John. Ross Hall, near Shrewsbury.
1862. *Harley, Rev. Robert, F.R.S., F.R.A.S. Lancaster-place, Leicester.
1861. ‡Harman, H. W., C.E. 16 Booth-street, Manchester.
1868. *Harmer, F. W., F.G.S. Heigham Grove, Norwich.
*Harris, Alfred. Sleningford Park, near Ripon.
*Harris, Alfred, jun. Ashfield, Bingley, Yorkshire.
1863. ‡Harris, Charles. 6 Somerset-terrace, Newcastle-on-Tyne.
Harris, The Hon. and Right Rev. Charles, Lord Bishop of Gibraltar, F.G.S. Care of A. Martineau, Esq., 61 Westbourne-terrace, London, W.
*Harris, Henry. Longwood, near Bingley.
1863. ‡Harris, T. W. Grange, Middlesborough-on-Tees.
1862. ‡Harris, William Harry, F.C.S. 33 Gold-street, Northampton.

Year of
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1860. ‡Harrison, Rev. Francis, M.A. Oriel College, Oxford.
1864. §Harrison, George. Barnsley, Yorkshire.
1858. *Harrison, James Park, M.A. Garlands, Ewhurst, Surrey.
1870. §Harrison, Reginald. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1853. *Harrison, William, F.S.A., F.G.S. Samlesbury Hall, near Preston, Lancashire.
1849. ‡Harrowby, The Earl of, K.G., D.C.L., F.R.S., F.R.G.S. 39 Grosvenor-square, London, S.W.; and Sandon Hall, Lichfield.
1859. *Hart, Charles. 54 Wych-street, Strand, London, W.C.
1861. *Harter, J. Collier. Chapel Walks, Manchester.
1842. *Harter, William. Hope Hall, Manchester.
1856. ‡Hartland, F. Dixon, F.S.A., F.R.G.S. The Oaklands, near Cheltenham.
Hartley, James. Sunderland.
Hartly, J. B. Bootle, near Liverpool.
1854. §Hartnup, John, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1850. ‡Harvey, Alexander. 4 South Wellington-place, Glasgow.
1870. §Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
*Harvey, Joseph Charles. Knockrea House, Cork.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-moors.
1855. ‡Hassall, Arthur Hill. 8 Bennett-street, St. James's, London, S.W.
Hastings, Rev. H. S. Martley Rectory, Worcester.
1842. *Hatton, James. Richmond House, Higher Broughton, Manchester.
1863. ‡Hatton, James W. Old Lodge, Old Trafford, Manchester.
Haughton, James, M.R.D.S. 34 Eccles-street, Dublin.
1857. ‡Haughton, Rev. Samuel, M.D., M.A., F.R.S., M.R.I.A., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
1857. ‡*Haughton, S. Wilfred. Grand Canal-street, Dublin.*
*Haughton, William. 28 City Quay, Dublin.
Hawkins, John Heywood, M.A., F.R.S., F.G.S. Bignor Park, Petworth, Sussex.
**Hawkins, Thomas, F.G.S.*
*Hawkshaw, John, F.R.S., F.G.S. 43 Eaton-place, and 33 Great George-street, London, S.W.
1864. *Hawkshaw, John Clarke, M.A., F.G.S. 43 Eaton-place, London, W.
1868. §Hawksley, Thomas, C.E. 30 Great George-street, Westminster, S.W.
1853. ‡Haworth, Benjamin. Hull Bank House, near Hull.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1861. *Hay, Rear-Admiral Sir John C. D., Bart., M.P., F.R.S. 108 St. George's-square, London, S.W.
1858. ‡Hay, Samuel. Albion-place, Leeds.
1867. ‡Hay, William. 21 Magdalen Yard-road, Dundee.
1857. ‡Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.
1870. §Hayden, Walter Percy. Halifax.
1869. ‡Hayward, J. High-street, Exeter.
1856. ‡Hayward, J. Curtis. Quedgeley, near Gloucester.
1858. *Hayward, Robert Baldwin, M.A. Harrow-on-the-hill.
1851. §Head, Jeremiah. Middlesborough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1869. ‡Head, W. R. Bedford-circus, Exeter.

Year of Election.

1861. *Heald, James. Parr's Wood, Didsbury, near Manchester.
1863. ‡Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1865. §Hearder, William. Victoria Parade, Torquay.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1861. §Heathfield, W. E., F.C.S., F.R.G.S., F.R.S.E. 20 King-street, St. James's, London, S.W.
1865. ‡Heaton, Harry. Warstone, Birmingham.
1858. *Heaton, John Deakin, M.D. Claremont, Leeds.
1865. ‡Heaton, Ralph. Harborne Lodge, near Birmingham.
1833. ‡Heaviside, Rev. Canon J. W. L., M.A. The Close, Norwich.
1863. ‡*Heckels, Richard.*
1855. ‡Hector, James, M.D., F.R.S., F.G.S., F.R.G.S., Geological Survey of Otago. Wellington, New Zealand.
1867. §Heddle, M. Foster, M.D., Professor of Chemistry in the University of St. Andrew's, N. B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1862. ‡Helm, George F. 58 Trumpington-street, Cambridge.
1857. *Hemans, George William, C.E., M.R.I.A.. 1 Westminster Chambers, Victoria-street, London, S.W.
1867. ‡Henderson, Alexander. Dundee.
1845. ‡Henderson, Andrew. 120 Gloucester-place, Portman-square, London.
1866. ‡Henderson, James, jun. Dundee.
1856. ‡Hennessy, Henry G., F.R.S., M.R.I.A. 86 St. Stephen's Green, Dublin.
1857. ‡Hennessy, John Pope. Inner Temple, London, E.C.
Henry, Franklin. Portland-street, Manchester.
Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell. Stratheden House, Hyde Park, London, W.
*Henry, William Charles, M.D., F.R.S., F.G.S., F.R.G.S. Haffield, near Ledbury, Herefordshire.
1870. §Henty, William. Norfolk-terrace, Brighton.
Henwood, William Jory, F.R.S., F.G.S. 3 Clarence-place, Penzance
1855. *Hepburn, J. Gotch. Sidcup-place, near Foot's Clay, Kent.
1855. ‡Hepburn, Robert. 70 Portland-place, London, W.
Hepburn, Thomas. Clapham, London, S.W.
Hepworth, John Mason. Ackworth, Yorkshire.
1856. ‡Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.
*Herbert, Thomas. The Park, Nottingham.
1852. ‡Herdman, John. 9 Wellington-place, Belfast.
1866. §Herrick, Perry. Bean Manor Park, Loughborough.
Herschel, Sir John Frederick William, Bart., K.H., M.A., D.C.L., F.R.S. L. & E., Hon. M.R.I.A., F.G.S., F.R.A.S. Collingwood, near Hawkhurst, Kent.
1861. ‡*Hertz, James. Sedgley-park, Prestwich, near Manchester.*
1865. ‡Heslop, Dr. Birmingham.
1863. ‡Heslop, Joseph. Pilgrim-street, Newcastle-on-Tyne.
1832. ‡Hewitson, William C. Oatlands, Surrey.
Hey, Rev. William, M.A., F.C.P.S. Clifton, York.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1866. ‡Heymann, L. West Bridgford, Nottinghamshire.
1861. *Heywood, Arthur Henry. The How, Prestwich, Manchester.
*Heywood, James, F.R.S., F.G.S., F.S.A., F.R.G.S. 26 Palace-gardens, Kensington, London, W.
1861. *Heywood, Oliver. Claremont, Manchester.
Heywood, Thomas Percival. Claremont, Manchester.

Year of Election.

1854. ‡*Heyworth, Captain L., jun.*
1870. *Heyworth, Lawrence. Yewtree, Liverpool.
1864. *Hiern, W. P., M.A. 1 Foxton-villa, Richmond, Surrey.
1854. *Higgin, Edward. 7 Queen's-road, St. John's Wood, London.
1861. *Higgin, James. 5 Hopwood-avenue, Manchester.
Higginbotham, Samuel. Exchange-square, Glasgow.
1866. ‡Higginbottom, John. Nottingham.
1861. ‡Higgins, George. Mount House, Higher Broughton, Manchester.
1854. ‡Higgins, Rev. Henry H., M.A. The Asylum, Rainhill, Liverpool.
1861. *Higgins, James. Stocks House, Cheetham, Manchester.
1870. §Higginson, Alfred. 44 Upper Parliament-street, Liverpool.
1842. *Higson, Peter, F.G.S., H.M. Inspector of Mines. The Brooklands, Swinton, near Manchester.
1870. §Highton, Rev. H. 2 The Cedars, Putney, S.W.
Hildyard, Rev. James, B.D., F.CP.S. Ingoldsby, near Grantham, Lincolnshire.
1862. *Hiley, Rev. Simeon. Elland, near Halifax.
Hill, Arthur. Bruce Castle, Tottenham, London, N.
*Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1857. ‡Hill, John. Tullamore, Ireland.
*Hill, Sir Rowland, K.C.B., D.C.L., F.R.S., F.R.A.S. Hampstead, London, N.W.
1864. ‡Hill, William. Combe Hay, Bristol.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1858. ‡Hincks, Rev. Thomas, B.A. Mountside, Leeds.
Hincks, Rev. William, F.L.S., Professor of Natural History in University College, Toronto, Canada West.
1870. §Hinde, G. J. Buenos Ayres.
Hindley, Rev. H. J. Edlington, Lincolnshire.
1852. *Hindmarsh, Frederick, F.G.S., F.R.G S. 4 New Inn, Strand, London, W.C.
*Hindmarsh, Luke. Alnbank House, Alnbank.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. ‡Hinds, William, M.D. Parade, Birmingham.
1861. *Hinmers, William. Cleveland House, Birkdale, Southport.
1858. §Hirst, John, jun. Dobcross, near Manchester.
1861. *Hirst, T. Archer, Ph.D., F.R.S, F.R.A.S. (General Secretary). The University of London, Burlington Gardens, W., and Athenæum Club, Pall Mall, London, S.W.
1856. ‡Hitch, Samuel, M.D. Sandywell Park, Gloucestershire.
1860. ‡Hitchman, John. Leamington.
1870. §Hitchman, William, M.D. 29 Erskine-street, Liverpool.
*Hoare, Rev. George Tooker. Godstone Rectory, Redhill.
Hoare, J. Gurney. Hampstead, London, N.W.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1863. §Hobson, A. S., F.C.S. 3 Upper Heathfield-terrace, Turnham Green, London, W.
1866. ‡Hockin, Charles, M.D. 8 Avenue-road, St. John's Wood, London.
1852. ‡Hodges, John F., M.D., Professor of Agriculture in Queen's College, Belfast. 23 Queen-street, Belfast.
1863. *Hodgkin, Thomas. Benwell Dene, Newcastle-on-Tyne.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
Hodgson, Thomas. Market-street, York.
1839. ‡Hodgson, W. B., LL.D., F.R.A.S. 41 Grove End-road, St. John's Wood, London, N.W.

Year of Election.

1860. ‡*Hogan, Rev. A. R., M.A.*
1865. *Hofmann, Augustus William, LL.D, Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
Hogan, William, M.A., M.R.I.A. Haddington-terrace, Kingstown, near Dublin.
1861. ‡Holcroft, George, C.E. Red Lion-court, St. Ann's-square, Manchester.
1854. *Holcroft, George. Byron's Court, St. Mary's Gate, Manchester.
1856. ‡Holland, Henry. Dumbleton, Evesham.
1858. §Holland, Loton, F.R.G.S. 6 Queen's-villas, Windsor.
*Holland, Philip H. 8 Richmond-terrace, Whitehall, London, S.W.
1865. ‡Holliday, William. New Street, Birmingham.
*Hollingsworth, John. Maidenstone House, Maidenstone Hill, Greenwich, Kent, S.E.
1866. *Holmes, Charles. London-road, Derby.
1870. §Holt, William D. 23 Edge-lane, Liverpool.
*Hone, Nathaniel, M.R.I.A. Bank of Ireland, Dublin.
1858. ‡Hook, The Very Rev. W. F., D.D., Dean of Chichester. Chichester.
1847. ‡Hooker, Joseph Dalton, C.B., M.D., D.C.L., LL.D., F.R.S., V.P.L.S. F.G.S., F.R.G.S. Royal Gardens, Kew.
1865. *Hooper, John P. The Hut, Mitcham Common, Surrey.
1861. §Hooper, William. 7 Pall Mall East, London, S.W.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
Hope, William. Wavertree, Liverpool.
1869. §Hope, William, V.C. Barking, Essex.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1870. *Hopkinson, F. 12 Dyke-place, Oxford-road, Manchester.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1864. *Horner, Rev. J. J. H. Mells Rectory, Frome.
1858. *Horsfall, Abraham. 17 Park-row, Leeds.
Horsfall, Charles. Everton, Liverpool.
1854. ‡Horsfall, Thomas Berry. Bellamour Park, Rugeley.
1856. ‡Horsley, John H. 389 High-street, Cheltenham.
Hotham, Rev. Charles, M.A., F.L.S. Roos, Patrington, Yorkshire.
1868. §Hotson, W. C. Upper King-street, Norwich.
1859. ‡Hough, Joseph. Wrottesley, near Wolverhampton.
Houghton, The Right Hon. Lord, D.C.L., F.R.S., F.R.G.S. 16 Upper Brook-street, London, W.
Houghton, James. 84 Rodney-street, Liverpool.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
Hovenden, W. F., M.A. Bath.
1859. ‡Howard, Captain John Henry, R.N. The Deanery, Lichfield.
1863. ‡Howard, Philip Henry. Corby Castle, Carlisle.
1857. ‡Howell, Henry H., F.G.S. Museum of Practical Geology, Jermyn-street, London, S.W.
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1868. ‡Howes, Edward, M.P. Morningthorpe, Long Stratton.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. §Howorth, H. H. Derby House, Eccles, Manchester.
1863. ‡Howse, R. South Shields.
1854. ‡Howson, Very Rev. J. S., Dean of Chester. Chester.
1870. §Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *Hudson, Henry, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London, S.W.

Year of Election.

1867. ‡Hudson, William H. H., M.A. St. John's College, Cambridge.
1858. *Huggins, William, D.C.L., Oxon., LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse-hill, Brixton, London, S.W.
1857. §Huggon, William. 30 Park-row, Leeds.
Hughes, D. Abraham. 9 Grays Inn-square, London, W.C.
Hughes, Frederick Robert.
1870. §Hughes, Lewis. 38 St. Domingo-grove, Liverpool.
1868. §Hughes, T. M'K., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1863. ‡Hughes, T. W. 4 Hawthorn-terrace, Newcastle-on-Tyne.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham.
Hull, Arthur H. 18 Norfolk-road, Brighton.
1867. §Hull, Edward, M.A., F.R.S., F.G.S. Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hull, William Darley, F.G.S. 36 Queen's Gate-terrace, South Kensington, London, W.
*Hulse, Sir Edward, Bart., D.C.L. 51 Portland-place, London, W.; and Breamore House, Salisbury.
1861. ‡Hume, Rev. Abraham, D.C.L., LL.D., F.S.A. All Soul's Rectory, Rupert-lane, Liverpool.
1856. ‡*Humphreys, E. R., LL.D.*
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *Humphry, George Murray, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. The Leys, Cambridge.
1863. *Hunt, Augustus H., M.A., Ph.D. Birtley House, Chester-le-Street, Fence Houses, Co. Durham.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1840. ‡Hunt, Robert, F.R.S., Keeper of the Mining Records. Museum of Practical Geology, Jermyn-street, London, S.W.
1864. ‡Hunt, W. 72 Pulteney-street, Bath.
Hunter, Andrew G. Denholm, Hawick.
1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.
1867. ‡Hunter, David. Blackness, Dundee.
1870. §Hunter, F. Appleton, Widnes.
1869. *Hunter, Rev. Robert, F.G.S. 9 Mecklenburg-street, London, W.C.
1859. ‡*Hunter, Dr. Thomas, Deputy Inspector-General of Army Hospitals.*
1855. *Hunter, Thomas O. 24 Forsyth-street, Greenock.
1863. ‡Huntsman, Benjaman. West Retford Hall, Retford.
1869. §Hurst, George. Bedford.
1861. *Hurst, Wm. John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
Husband, William Dalla. Coney-street, York.
1868. *Hutchison, Robert. 29 Chester-street, Edinburgh.
1863. ‡Hutt, The Right Hon. Sir W., K.C.B., M.P. Gibside, Gateshead.
Hutton, Crompton. Putney-park, Surrey, S.W.
Hutton, Daniel. 4 Lower Dominick-street, Dublin.
1864. *Hutton, Darnton. Care of Arthur Lupton, Esq., Headingley, near Leeds.
1857. ‡Hutton, Henry D. 10 Lower Mountjoy-street, Dublin.
*Hutton, Robert, M.R.I.A., F.G.S. Putney Park, Surrey.
1861. ‡Hutton, T. Maxwell. Summerhill, Dublin.
1852. ‡Huxley, Thomas Henry, Ph.D., LL.D., F.R.S., F.L.S., F.G.S. (President), Professor of Natural History in the Royal School of Mines. 26 Abbey Place, St. John's Wood, London.
1846. ‡Huxtable, Rev. Anthony. Sutton Waldron, near Blandford.
Hyde, Edward. Dukinfield, near Manchester.
Hyett, William Henry, F.R.S. Painswick, near Stroud, Gloucestershire.
1847. ‡Hyndman, George C. 5 Howard-street, Belfast.

Year of Election.

Ihne, William, Ph.D. Heidelberg.
1861. ‡Iles, Rev. J. H. Rectory, Wolverhampton.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1858. *Ingram, Hugo Francis Meynell. Temple Newsam, Leeds.
1852. ‡Ingram, J. K., LL.D., M.R.I.A., Regius Professor of Greek. Trinity College, Dublin.
1854. *Inman, Thomas, M.D. 12 Rodney-street, Liverpool.
1870. *Inman, William. Upton Manor, Liverpool.
1856. ‡*Invararity, J. D. Bombay.*
Ireland, R. S., M.D. 121 Stephen's Green, Dublin.
1857. ‡Irvine, Hans, M.A., M.B. 1 Rutland-square, Dublin.
Irwin, Rev. Alexander, M.A. Armagh, Ireland.
1862. ‡Iselin, J. F., M.A., F.G.S. 52 Stockwell Park-road, London, S.W.
1863. *Ivory, Thomas. 9 Ainslie-place, Edinburgh.

1865. ‡Jabet, George. Wellington-road, Handsworth, Birmingham.
1870. §Jack, James. 26 Abercromby-square, Liverpool.
1859. §Jack, John, M.A. Belhelvie by Whitecairns, Aberdeenshire.
1863. *Jackson-Gwilt, Mrs. H. 24 Hereford-square, Gloucester-road, Old Brompton, London, S.W.
1865. ‡*Jackson, Edwin.*
1858. ‡*Jackson, Edwin W.*
1866. §Jackson, H. W. Springfield, Tooting, Surrey, S.W.
1869. §Jackson, Moses. The Vale, Ramsgate.
Jackson, Professor Thomas, LL.D. St. Andrew's, Scotland.
1855. ‡*Jackson, Rev. William, M.A.*
Jacob, Arthur, M.D. 23 Ely-place, Dublin.
1852. ‡Jacobs, Bethel. 40 George-street, Hull.
1867. *Jaffe, David Joseph. (Messrs. Jaffe Brothers) Belfast.
1865. *Jaffray, John. 'Daily Post' Office, New-street, Birmingham.
1859. ‡James, Edward. 9 Gascoyne-terrace, Plymouth.
1860. ‡James, Edward H. 9 Gascoyne-terrace, Plymouth.
James, Colonel Sir Henry, R.E., F.R.S., F.G.S., M.R.I.A. Ordnance Survey Office, Southampton.
1863. *James, Sir Walter. 6 Whitehall-gardens, London, S.W.
1858. ‡James, William C. 9 Gascoyne-terrace, Plymouth.
1863. ‡Jameson, John Henry. 10 Catherine-terrace, Gateshead.
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. §Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
Jardine, James, C.E., F.R.A.S. Edinburgh.
*Jardine, Sir William, Bart., F.R.S.L. & E., F.L.S. Jardine Hall, Applegarth by Lockerby, Dumfriesshire.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
Jarrett, Rev. Thomas, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1870. §Jarrold, J. J. London-street, Norwich.
1862. ‡Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, W.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1868. §Jecks, Charles. Billing-road, Northampton.
1842. **Jee, Alfred S.*
1870. §Jeffery, F. J. Woolton Hall, near Liverpool.
1856. ‡Jeffery, Henry, M.A. 438 High-street, Cheltenham.
1855. *Jeffray, John. 193 St. Vincent-street, Glasgow.
1867. ‡Jeffreys, Howell. Balliol College, Oxford.
1861. *Jeffreys, J. Gwyn, F.R.S., F.L.S., F.G.S., F.R.G.S. 25 Devonshire-place, Portland-place, London, W.

Year of Election.

1852. ‡Jellett, Rev. John H., M.A., M.R.I.A., Professor of Natural Philosophy in Trinity College, Dublin. 64 Upper Leeson-street, Dublin.
1842. Jellicorse, John. Chaseley, near Rugeley, Staffordshire.
1864. ‡*Jelly, Dr. W. Paston Hall, near Peterborough.*
1862. §Jenkin, H. C. Fleeming, F.R.S., Professor of Civil Engineering in the University of Edinburgh. 5 Fettes-row, Edinburgh.
1864. §Jenkins, Captain Griffith, C.B., F.R.G.S. Derwin, Welshpool.
*Jenkyns, Rev. Henry, D.D. The College, Durham.
Jennette, Matthew. 106 Conway-street, Birkenhead.
1852. §Jennings, Francis M., F.G.S., M.R.I.A. Brown-street, Cork.
1861. ‡Jennings, Thomas. Cork.
*Jenyns, Rev. Leonard, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
1870. §Jerdon, T. C. Care of Mr. H. S. King, 45 Pall Mall, London, S.W.
1870. §Jervons, Walter S., M.D. Ashburton, Devon.
*Jerram, Rev. S. John, M.A. Chobham Vicarage, Farnborough Station.
Jessop, William, jun. Butterley Hall, Derbyshire.
1870. *Jevons, W. Stanley, M.A., Professor of Political Economy in Owens College, Manchester. Writhington, Manchester.
1865. *Johnson, G. J. 243 Hagley-road, Birmingham.
1866. §Johnson, John. Low Pavement, Nottingham.
1866. §Johnson, John G. 18A Basinghall-street, London, E.C.
1868. ‡Johnson, J. Godwin. St. Giles's-Street, Norwich.
1868. ‡Johnson, Randall J. Sandown-villa, Harrow.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
1861. ‡Johnson, Richard. 27 Dale-street, Manchester.
1870. §Johnson, Richard C. Warren Side, Blundell Sands, Liverpool.
*Johnson, Thomas. The Hermitage, Frodsham, Cheshire.
1864. ‡Johnson, Thomas. 30 Belgrave-street, Commercial-road, London, E.
Johnson, William. The Wynds Point, Colwall, Malvern, Worcestershire.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.
1849. ‡Johnston, Alexander Keith, LL.D., F.R.S.E., F.G.S., F.R.G.S. 4 St. Andrew-square, Edinburgh.
Johnston, Alexander Robert, F.R.S. The Grove, Yoxford, Suffolk.
1859. ‡*Johnston, David, M.D.*
1864. ‡Johnston, David. 13 Marlborough-buildings, Bath.
Johnston, Edward. Field House, Chester.
1859. ‡Johnston, James. Newmill, Elgin, N. B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.
*Johnstone, James. Aloa House, by Stirling.
1864. ‡Johnstone, John. 1 Barnard-villas, Bath.
Jollie, Walter. Edinburgh.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.
1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.
Jones, Rev. Harry Longueville.
1858. ‡Jones, Henry Bence, M.A., M.D., D.C.L., F.R.S., Hon. Sec. to the Royal Institution. 84 Brook-street, London, W.
1854. ‡Jones, Rev. Henry H. Cemetery, Manchester.
1854. ‡Jones, John. 70 Rodney-street, Liverpool.
1864. §Jones, John, F.G.S. Royal Exchange, Middlesborough.
1865. ‡Jones, John. 49 Union-passage, Birmingham.
*Jones, Robert. 2 Castle-street, Liverpool.
1854. *Jones, R. L. 6 Sunnyside, Princes Park, Liverpool.
1847. ‡Jones, Thomas Rymer, Professor of Comparative Anatomy in King's College. 50 Cornwall-road, Westbourne-park, London, W.

Year of
Election.

1860. ‡Jones, T. Rupert, F.G.S., Professor of Geology and Mineralogy, Royal Military College, Sandhurst. 5 College-terrace, York Town, Surrey.

1864. §Jones, Sir Willoughby, Bart, F.R.G.S. Cranmer Hall, Fakenham, Norfolk.

1851. ‡Josselyn, G. Tower-street, Ipswich.

*Joule, Benjamin St. John B. 28 Leicester-street, Southport, Lancashire.

1842. *Joule, James Prescott, LL.D., F.R.S., F.C.S. 5 Cliff Point, Higher Broughton, Manchester.

1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, near Wantage, Berkshire.

Joy, Henry Holmes, LL.D., Q.C., M.R.I.A. 17 Mountjoy-square East, Dublin.

Joy, William B., M.D. 48 Leeson-street, Dublin.

1847. ‡Jowett, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.

1858. ‡Jowett, John, jun. Leeds.

*Jubb, Abraham. Halifax.

1870. §Judd, John Wesley, F.G.S. Geological Museum, Jermyn-street, London, S.W.

1863. ‡Jukes, Rev. Andrew. Spring Bank, Hull.

1868. *Kaines, Joseph, F.A.S.L. 8 Osborne-road, Stroud Green-lane, Hornsey.

Kane, Sir Robert, M.D., F.R.S., M.R.I.A., Principal of the Royal College of Cork. 51 Stephen's Green, Dublin.

1857. ‡Kavanagh, James W. Grenville, Rathgar, Ireland.

1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington.

Kay, John Cunliff. Fairfield Hall, near Skipton.

*Kay, John Robinson. Walmersley House, Bury, Lancashire.

Kay, Robert. Haugh Bank, Bolton-le-Moors.

1847. *Kay, Rev. William, D.D. Great Leighs Rectory, Chelmsford.

1856. ‡Kay-Shuttleworth, Sir James, Bart. Gawthorpe, Burnley.

1855. ‡Kaye, Robert. Mill Brae, Moodies Burn, by Glasgow.

1855. ‡Keddie, William. 15 North-street, Mungo-street, Glasgow.

1866. ‡Keene, Alfred. Eastnoor House, Leamington.

1850. ‡Kelland, Rev. Philip, M.A., F.R.S.L. & E., Professor of Mathematics in the University of Edinburgh. 20 Clarendon Crescent, Edinburgh.

1849. ‡Kelly, John, C.E. 38 Mount Pleasant-square, Dublin.

1857. ‡Kelly, John J. 38 Mount Pleasant-square, Dublin.

1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.

1842. Kelsall, J. Rochdale, Lancashire.

1864. *Kemble, Rev. Charles, M.A. Vellore, Bath.

1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.

1858. ‡Kemplay, Christopher. Leeds.

1857. ‡Kennedy, Lieut-Colonel John Pitt. 20 Torrington-square, Bloomsbury, London, W.C.

Kenny, Matthias, M.D. 3 Clifton-terrace, Monkstown, Co. Dublin.

Kenrick, Rev. George.

1865. ‡Kenrick, William. Norfolk-road, Edgbaston, Birmingham.

Kent, J. C. Levant Lodge, Earl's Croome, Worcester.

1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.

1857. ‡Kenworth, James Ryley. 7 Pembroke-place, Liverpool.

1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.

1855. *Ker, Robert. Auchinraith, by Hamilton, Scotland.

1865. *Kerr, William D., M.D., R.N. Bonnyrigg, Edinburgh.

Year of Election.

1868. ‡Kerrison, Roger. Crown Bank, Norwich.
1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.
1869. *Kesselmeyer, William Johannes. 1 Peter-street, Manchester.
1861. *Keymer, John. Parker-street, Manchester.
1865. *Kinahan, Edward Hudson. 11 Merrion-square North, Dublin.
1860. ‡Kinahan, G. Henry, M.R.I.A. Geological Survey of Ireland, 51 Stephen's Green, Dublin.
1858. ‡Kincaid, Henry Ellis, M.A. 8 Lyddon-terrace, Leeds.
1855. ‡King, Alfred, jun. Everton, Liverpool.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1870. §King, John Thomson, C.E. 4 Clayton-square, Liverpool.
King, Joseph. Blundell Sands, Liverpool.
1864. §King, Kelburne, M.D. 27 George Street, and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. Avonside, Clifton Down, Bristol.
1842. King, Richard, M.D. 12 Bulstrode-street, London, W.
King, Rev. Samuel, M.A., F.R.A.S. St. Aubins, Jersey.
1870. §King, William. 13 Adelaide-terrace, Waterloo, Liverpool.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1869. ‡Kingdon, B. Rose Hill, Exeter.
1869. ‡Kingdon, K. Taddiford, Exeter.
1862. ‡Kingsley, Rev. Canon Charles, M.A., F.L.S., F.G.S. Eversley Rectory, Winchfield.
1861. ‡Kingsley, John. 30 St. Ann's-street, Manchester.
1845. ‡Kingsley, Rev. W. T. South Kelvington, Thirsk.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1870. §Kinsman, William R. Bank of England, Liverpool.
1867. *Kinnaird, The Hon. Arthur Fitzgerald, M.P. 1 Pall Mall East, London, S.W.; and Rossie Priory, Inchture, Perthshire.
1863. ‡Kinnaird, The Right Hon. Lord., K.T., F.G.S. Rossie Priory, Inchture, Perthshire.
Kinnear, J. G., F.R.S.E. Glasgow.
1863. ‡Kirkaldy, David. 28 Bartholomew-road North, London, N.W.
1860. ‡Kirkman, Rev. Thomas P., M.A., F.R.S. Croft Rectory, near Warrington.
Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1850. ‡Kirkwood, Anderson. 151 West George-street, Glasgow.
1849. ‡Kirshaw, John William, F.G.S. Warwick.
1868. §Kirwan, Rev. Richard, M.A. Gittesham Rectory, near Honiton.
1870. §Kitchener, Frank E. Rugby.
1858. ‡Kitson, James. Leeds.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. §Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.
Knight, Sir A. J., M.D.
Knipe, J. A. Botcherby, Carlisle.
1842. Knowles, John. Old Trafford Bank House, Old Trafford, Manchester.
1870. §Knowles, Rev. J. L. Grove Villa, Bushey, Herts.
Knox, Rev. H. B., M.A., M.R.I.A. Deanery, Hadleigh, Suffolk.
1861. **Killmann, Max.*
1870. §Kynaston, Josiah W. St. Helens, Lancashire.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

Lace, Ambrose.
1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1862. ‡Lackerstein, Dr. (Care of Messrs. Smith and Elder, 15 Waterloo-place, London, S.W.)

Year of Election.

1859. §Ladd, William, F.R.A.S. 11 & 13 Beak-street, Regent-street, London, W.
1850. ‡Laing, David, F.S.A. Scotl. Signet Library, Edinburgh.
1870. §Laird, H. H. Birkenhead.
Laird, John, M.P. Hamilton-square, Birkenhead.
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead.
1859. ‡Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co. Dublin.
Lambert, Richard.
1846. *Laming, Richard. 10 Gloucester-place, Brighton.
1870. §Lamport, C. Upper Norwood, Surrey.
1859. ‡Lang, Rev. John Marshall. Fyvie, Aberdeen.
1864. §Lang, Robert. Hallen Lodge, Henbury, Bristol.
1870. §Langton, Charles. Barkhill, Aigburth, Liverpool.
*Langton, William. Manchester.
1840. ‡Lankester, Edwin, M.D., LL.D., F.R.S., F.L.S. 23 Great Marlborough-street, London, W.
1865. §Lankester, E. Ray. Melton House, Hampstead, London, N.W.
*Larcom, Major-General Sir Thomas Aiskew, K.C.B., R.E., F.R.S., M.R.I.A. Heathfield House, Fareham, Hants.
Lassell, William, F.R.S., F.R.A.S. Ray Lodge, Maidenhead.
1860. ‡*Lassell, William, jun. The Brook, near Liverpool.*
1861. *Latham, Arthur G. 24 Cross-street, Manchester.
1845. ‡Latham, Robert G., M.A., M.D., F.R.S. 96 Disraeli-road, Putney, S.W
*La Touche, David Charles, M.R.I.A. Castle-street, Dublin.
1870. §Laughton, John Knox, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Portsmouth.
1870. *Law, Channell. 5 Champion Park, Camberwell, London, S.E.
1857. ‡Law, Hugh. 4 Great Denmark-street, Dublin.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Law, Rev. William, M.A.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. §Lawrence, Edward. Aigburth, Liverpool.
1869. ‡Lawson, Henry. 8 Nottingham-place, London, W.
1857. ‡Lawson, James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1855. ‡Lawson, John. Mountain Blue Works, Camlachie.
1868. *Lawson, M. Alexander, M.A., F.L.S., Professor of Botany in the University of Oxford. Botanic Gardens, Oxford.
1858. ‡*Lawson, Samuel. Kirkstall, near Leeds.*
1863. ‡Lawton, Benjamin C. Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne.
1853. ‡Lawton, William. 8 Manor House-street, Hull.
Laycock, Thomas, M.D., Professor of the Practice of Physic in the University of Edinburgh. 4 Rutland-street, Edinburgh.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Capt. R. E. Mountjoy, Phœnix Park, Dublin.
Leadbetter, John. Glasgow.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London E.C.; and Harrow.
1870. *Leatham, Baldwin. 7 Westminster Chambers, Westminster, S.W.
1847. *Leatham, Edward Aldam, M.P. Whitley Hall, Huddersfield.
1858. ‡Leather, George. Knostrop, near Leeds.
*Leather, John Towlerton. Leventhorpe Hall, near Leeds.
1858. ‡Leather, John W. Newton Green, Leeds.
1863. ‡Leavers, J. W. The Park, Nottingham.
1858. *Le Cappelain, John. Wood-lane, Highgate, London, N.

Year of
Election.

1858. ‡Ledgard, William. Potter Newton, near Leeds.
1842. Lee, Daniel. Springfield House, Pendlebury, Manchester.
1861. ‡Lee, Henry. Irwell House, Lower Broughton, Manchester.
Lee, Henry, M.D. Weatheroak, Alve Church, near Bromsgrove.
1853. *Lee, John Edward, F.G.S., F.S.A. The Priory, Caerleon, Monmouthshire.
1850. ‡Lees, George, LL.D. Rillbank, Edinburgh.
1859. ‡Lees, William. 5 Meadow Bank, Edinburgh.
*Leese, Joseph. Glenfield, Altrincham, near Manchester.
*Leeson, Henry B., M.A., M.D., F.R.S., F.C.S The Maples, Bonchurch, Isle of Wight.
*Lefroy, J. Henry, Major-General, R.A., F.R.S., F.R.G.S., Director-General of Ordnance. 82 Queen's Gate, London, W.
*Legh, George Cornwall, M.P. High Legh Hall, Cheshire; and 6 St. James's-place, St. James's-street, London, S.W.
1869. §Le Grice, A. J. Trereife, Penzance.
1868. ‡Leicester, The Right Hon. The Earl of. Holkham, Norfolk.
1856. ‡Leigh, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1870. §Leighton, Andrew. 35 High Park-street, Liverpool.
*Leinster, Augustus Frederick, Duke of, M.R.I.A. 6 Carlton House-terrace, London, S.W.; and Carton, Maynooth, Ireland.
1867. §Leishman, James. Gateacre Hall, Liverpool.
1870. §Leister, G. F. Gresbourn House, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N. B.
1860. ‡Lempriere, Charles, D.C.L. St. John's College, Oxford.
1863. *Lendy, Capt. Auguste Frederic, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex, S.W.
1867. ‡Leng, John. "Advertiser" Office, Dundee.
1861. ‡Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.
Lentaigne, John, M.D. Tallaght House, Co. Dublin; and 14 Great Dominick-street, Dublin.
Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.
1856. ‡Leslie, Colonel J. Forbes. Bothiekorman, Aberdeenshire.
1852. ‡Leslie, T. E. Cliffe, LL.B., Professor of Jurisprudence and Political Economy, Queen's College, Belfast.
1859. ‡Leslie, William. Warthill, Aberdeenshire.
1846. ‡Letheby, Henry, M.B., F.L.S., Medical Officer to the City of London. 41 Finsbury-square, London, E.C.
1866. §Levi, Dr. Leone, F.S.A., F.S.S., Professor of Commercial Law in King's College, London. 10 Farrar's-building, Temple, London, E.C.
1870. §Lewis, Alfred Lionel. 45 Church-road, De Beauvoir-square, London, N.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡Liddell, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1855. ‡Liddell, John. 8 Clelland-street, Glasgow.
1859. ‡Ligertwood, George. Blair by Summerhill, Aberdeen.
1864. §Lightbody, Robert, F.G.S. Ludlow, Salop.
1862. ‡Lilford, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*Limerick, Charles Graves, D.D., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
*Lindsay, Charles. Ridge-park, Lanark.
*Lindsay, Henry L., C.E., M.R.I.A. 1 Little Collins-street West, Montreal, Canada.

Year of Election.

1855. *Lindsay, John H. Care of James Jarvie, Esq., 7 Steven-street, Glasgow.
1870. §Lindsay, Thomas. 288 Renfrew-street, Glasgow.
1842. *Lingard, John R., F.G.S. Mayfield, Shortlands, by Bromley, Kent.
Lingwood, Robert M., M.A., F.L.S., F.G.S. Cowley House, Exeter.
Lister, James. Liverpool Union Bank, Liverpool.
1870. §Lister, Thomas. Post Office, Barnsley.
Littledale, Harold. Liscard Hall, Cheshire.
1861. *Liveing, G. D., M.A., F.C.S., Professor of Chemistry in the University of Cambridge. Newnham, Cambridge.
1864. §Livesay, J. G. Cromarty House, Ventnor, Isle of Wight.
1860. ‡Livingstone, Rev. Thomas Gott, Minor Canon of Carlisle Cathedral.
Lloyd, Rev. A. R. Hengold, near Oswestry.
Lloyd, Rev. C., M.A. Whittington, Oswestry.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B. Wellington-road, Edgbaston, Birmingham.
*Lloyd, George, M.D., F.G.S. Birmingham Heath, Birmingham.
1870. §Lloyd, James. 150 Chatham-street, Liverpool.
1870. §Lloyd, J. B.
1870. §Lloyd, J. H., M.D. Anglesea.
*Lloyd, Rev. Humphrey, D.D., LL.D., F.R.S. L. & E., M.R.I.A., Provost of Trinity College, Dublin.
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1865. *Lloyd, Wilson. Moor Hall, Sutton Coldfield, near Birmingham.
1854. *Lobley, James Logan, F.G.S., F.R.G.S. 50 Lansdowne-road, Kensington Park, London, W.
1853. *Locke, John. Care of J. Robertson, Esq., 3 Grafton-street, Dublin.
1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1863. ‡Lockyer, J. Norman, F.R.S., F.R.A.S. 24 Victoria-road, Finchley-road, London, N.W.
1853. ‡Loft, John. 17 Albion-street, Hull.
**Loftus, William Kennett, F.G.S. Calcutta.*
*Logan, Sir William Edmond, LL.D., F.R.S., F.G.S., F.R.G.S., Director of the Geological Survey of Canada. Montreal, Canada.
1868. ‡Login, Thomas, C.E., F.R.S.E. 1 Leamington-villas, Weston-super-Mere.
1862. ‡Long, Andrew, M.A. King's College, Cambridge.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1866. §Longdon, F. Derby.
1857. ‡Longfield, Rev. George, D.D. 25 Trinity College, Dublin.
Longfield, Mountifort, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam-square, Dublin.
1861. *Longman, William, F.G.S. 36 Hyde Park-square, London, W.
1859. ‡Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
Longridge, W. S. Oakhurst, Ambergate, Derbyshire.
1865. *Longsdon, Robert. Church House, Bromley, Kent.
1861. *Lord, Edward. Adamroyd, Todmorden.
1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1867. §Low, James F. Monifieth, by Dundee.
1863. *Lowe, Major Arthur S. H., F.R.A.S. 76 Lancaster Gate, London.
1861. *Lowe, Edward Joseph, F.R.S., F.R.A.S., F.L.S., F.G.S., F.M.S. Highfield House Observatory, near Nottingham.
Lowe, George, F.R.S., F.G.S., F.R.A.S. 9 St. John's-wood Park, London, N.W.

Year of
Election.

1870. §Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.
1868. ‡Lowe, John, M.D. King's Lynn.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
Lowndes, Matthew D.
1853. *Lubbock, Sir John, Bart., M.P., F.R.S., F.L.S., F.G.S. High Elms, Farnborough, Kent.
1870. §Lubbock, Montague. High Elms, Farnborough, Kent.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1867. *Luis, John Henry. Cidhmore, Dundee.
1866. *Lund, Charles. Market-street, Bradford.
1850. *Lundie, Cornelius. Tweed Lodge, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1858. *Lupton, Arthur. Headingley, near Leeds.
1864. *Lupton, Darnton, Jun. The Harehills, Leeds.
1866. §Lycett, Sir Francis. 18 Highbury-grove, London, N.
*Lyell, Sir Charles, Bart., M.A., LL.D., D.C.L., F.R.S., F.L.S., V.P.G.S., Hon. M.R.S.Ed. 73 Harley-street, London, W.
1864. ‡Lyne, Francis. (Care of Sydney Smith, Esq., Charlotte-row, Mansion House, London, E.C.)
1857. ‡Lyons, Robert D. 31 Upper Merrion-street, Dublin.
1862. *Lyte, Maxwell F., F.C.S. Bagnères de Bigorre, France.
1849. ‡Lyttelton, The Right Hon. Lord, D.C.L., F.R.S. 12 Stratton-street, London, W.

1859. ‡Mabson, John. Heyning, Westmoreland.
1852. ‡*MacAdam, James, jun. Beavor Hall, Belfast.*
1852. ‡MacAdam, Robert. 18 College-square East, Belfast.
1854. *Macadam, Stevenson, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh.
1868. ‡Macalister, Alexander, M.D., Professor of Zoology in the University of Dublin. 13 Adelaide-road, Dublin.
1868. ‡M'Allan, W. A. Norwich.
*M'Andrew, Robert, F.R.S. Isleworth House, Isleworth, Middlesex.
1866. *M'Arthur, A. Raleigh Hall, Brixton Rise, London, S.W.
1855. ‡*M'Arthur, Richard, W. J.*
1840. Macaulay, James, M.D. 22 Cambridge-road, Kilburne, London, N.W.
1857. ‡*Macauley, James William.*
*MacBrayne, Robert. Messrs. Black and Wingate, 9 Exchange-square, Glasgow.
1866. ‡M'Callan, Rev. J. F., M.A. Basford, near Nottingham.
1855. ‡M'Callum, Archibald K., M.A. House of Refuge, Duke-street, Glasgow.
1863. ‡M'Calmont, Robert. Gatton Park, Reigate.
1855. ‡M'Cann, James, F.G.S. Holmfrith, Yorkshire.
1857. ‡M'Causland, Dominick. 12 Fitzgibbon-street, Dublin.
1865. *M'Clean, John Robinson, F.R.S., F.G.S. 2 Park-street, Westminster, S.W.
1840. M'Clelland, James. 32 Pembridge Square, London, W.
1856. ‡*M'Clelland, John. Calcutta.*
1868. ‡M'Clintock, Captain Sir Francis L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
*M'Connel, James. The Furze, Esher, Surrey.
1859. **M'Connell, David C., F.G.S.*
1858. ‡M'Connell, J. E. Woodlands, Great Missenden.
1852. ‡M'Cosh, Rev. James, M.A. Canada.

Year of Election.

1851. ‡M'Coy, Frederick, F.G.S., Professor of Zoology and Natural History in the University of Melbourne, Australia.
M'Cullagh, John, A. B.
*M'Culloch, George, M.D. Cincinnati, United States.
Macdonald, William, M.D., F.R.S.E., F.L.S., F.G.S., Professor of Civil and Natural History. St. Andrews, N. B.
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
*M'Ewan, John. 20 Royal Crescent, Glasgow.
1850. ‡Macfarlan, John Fletcher. Park-place, Edinburgh.
1859. ‡Macfarlane, Alexander. 73 Bon Accord-street, Aberdeen.
1855. ‡M'Farlane, Walter. Saracen Foundry, Glasgow.
1854. *Macfie, Robert Andrew, M.P. Ashfield Hall, Neston, near Chester.
1867. *M'Gavin, Robert. Ballumbie, Dundee.
1852. *M'Gee, William, M.D. 10 College-square North, Belfast.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1855. ‡M'Gregor, Alexander Bennett. 19 Woodside-crescent, Glasgow.
1855. ‡MacGregor, James Watt. Wallace-grove, Glasgow.
1859. ‡M'Hardy, David. 54 Netherkinkgate, Aberdeen.
1855. ‡M'Ilwraith, H. Greenock.
1859. ‡Macintosh, John. Middlefield House, Woodside, Aberdeen.
1867. *M'Intosh, W. C., M.D., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. Water-street, Liverpool.
1865. ‡*Mackeson, H. B.*
1865. ‡Mackintosh, Daniel, F.G.S. Chichester.
1855. ‡M'Kenzie, Alexander. 89 Buchanan-street, Glasgow.
*Mackenzie, James. Glentore, by Glasgow.
1850. ‡Mackenzie, J. W. 16 Royal Circus, Edinburgh.
1865. ‡*Mackenzie, Kenneth Robert Henderson, F.S.A., F.A.S.L.*
1859. ‡Mackie, David. Mitchell-place, Aberdeen.
1867. §Mackie, Samuel Joseph, F.G.S. 84 Kensington Park-road, London, W.
*Mackinlay, David. Pollokshields, Glasgow.
1867. §Mackson, H. G. 25 Cliff Road, Woodhouse, Leeds.
1850. ‡Maclagan, Douglas, M.D., F.R.S.E. 28 Heriot Row, Edinburgh.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. §MacLaren, Duncan, M.P. Newington House, Edinburgh.
1855. ‡*MacLaren, John.*
1859. ‡Maclear, Sir Thomas, F.R.S., F.R.G.S., F.R.A.S., late Astronomer Royal at the Cape of Good Hope.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Camden-hill-road, London, W.
1868. §M'Leod, Herbert. Royal College of Chemistry, Oxford-street, London, W.
1855. ‡*M'Lintock, William.*
1861. *Maclure, John William. 2 Bond-street, Manchester.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey.
1870. §Macnaught, John, M.D. 50 Bedford-street, Liverpool.
1867. §M'Neill, John. Balhousie House, Perth.
MacNeill, The Right Hon. Sir John, G.C.B., F.R.S.E., F.R.G.S. Granton House, Edinburgh.
MacNeill, Sir John, LL.D., F.R.S., M.R.I.A., Professor of Civil Engineering in Trinity College, Dublin. Mount Pleasant, Dundalk.
1850. ‡Macnight, Alexander. 12 London-street, Edinburgh.
1859. ‡Macpherson, Rev. W. Kilmuir Easter, Scotland.
Macredie, P. B. Mure, F.R.S.E. Irvine, Ayrshire.
1852. *Macrory, Adam John. Duncairn, Belfast.

Year of Election.

*Macrory, Edmund, M.A. 40 Leinster-square, Bayswater, London, W.
1855. ‡M'Tyre, William, M.D. Maybole, Ayrshire.
1855. ‡Macvicar, Rev. John Gibson, D.D., LL.D. Moffat, N.B.
1857. ‡*Madden, Richard R.*
1868. ‡Magnay, F. A. Drayton, near Norwich.
Magor, J. B. Redruth, Cornwall.
1869. §Main, Rev. R., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1869. ‡Main, Robert. Admiralty, Somerset House, W.C.
1866. §Major, Richard H., F.S.A., F.R.G.S. British Museum, London, W.C.
*Malahide, Talbot de, The Right Hon. Lord, M.A., F.R.S., F.G.S., F.S.A. Malahide Castle, Co. Dublin.
1853. ‡Malan, John. Holmpton, Holderness.
*Malcolm, Frederick. Mordon College, Blackheath, London, S.E.
1850. ‡Malcolm, R. B., M.D., F.R.S.E. 126 George-street, Edinburgh.
1870. *Malcolm, Sir James, Bart. The Priory, St. Michael's Hamlet, Aigburth, Liverpool.
1863. ‡Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.
*Mallet, Robert, Ph.D., F.R.S., F.G.S., M.R.I.A. The Grove, Clapham-road, Clapham, London, S.W.
1857. ‡Mallet, Dr. John William. University of Alabama, U. S.
1846. ‡Manby, Charles, F.R.S., F.G.S. 24 Great George-street, London, S.W.
1863. ‡*Mancini, Count de, Italian Consul.*
1866. §Mann, Robert James, M.D., F.R.A.S. 6 Duke-street, Adelphi, Lon-London, W.C.; and 4 Belmont-villas, Surbiton Hill.
Manning, The Right Rev. H.
1866. ‡Manning, John. Waverley-street, Nottingham.
1870. §Manifold, W. H. 45 Rodney-street, Liverpool.
1864. ‡Mansel, J. C. Long Thorns, Blandford.
1865. ‡March, J. F. Fairfield House, Warrington.
1870. §Marcoartu, Senor Don Arturo de. Madrid.
1864. ‡Markham, Clements R., F.L.S., F.R.G.S. 21 Eccleston-square, Pimlico, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
*Marling, Samuel S., M.P. Stanley Park, Stroud, Gloucestershire.
Marriott, John. Allerton, Liverpool.
1857. §Marriott, William. Grafton-place, Huddersfield.
1858. ‡Marriott, William Thomas. Wakefield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1866. ‡Marsh, Dr. J. C. L. Park-row, Nottingham.
1870. §Marsh, John. Rann Lea, Rainhill, Liverpool.
1856. ‡Marsh, M. H. Wilbury Park, Wilts.
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
Marshall, James. Headingly, near Leeds.
1852. ‡Marshall, James D. Holywood, Belfast.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
*Marshall, James Garth, M.A., F.G.S. Headlingley House, Leeds.
1849. *Marshall, William P. 6 Portland-road, Edgbaston, Birmingham.
1865. §Marten, Edward Bindon. 13 High-street, Stourbridge.
1848. ‡Martin, Henry D. 4 Imperial Circus, Cheltenham.
1870. §Martin, Robert, M.D. 120 Upper Brook-street, Manchester.
1836. Martin, Studley. 177 Bedford-street South, Liverpool.
1867. *Martin, William, Jun. Leafield-place, Dundee.
*Martindale, Nicholas. 12 Cornwall-terrace, Regent's Park, London, N.W.

Year of Election.

*Martineau, Rev. James. 10 Gordon-street, Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1847. ‡Maskelyne, Nevil Story, F.R.S., M.A., F.G.S., Professor of Mineralogy in the University of Oxford. British Museum, London, W.C.
1861. *Mason, Hugh. Groby Lodge, Ashton-under-Lyne.
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1870. §Massey, Thomas. 5 Gray's-Inn-square, London, W.C.
1870. §Massy, Frederick. 50 George-street, Liverpool.
1868. §Mason, James Wood, F.G.S. 1 Glebe-place, Stoke Newington, London, N.
1863. *Mather, Joseph. Beech Grove, Newcastle-on-Tyne.
1865. *Mathews, G. S. 15 Waterloo-street, Birmingham.
1861. *Mathews, William, jun., M.A., F.G.S. 51 Carpenter-road, Edgbaston, Birmingham.
1859. ‡Matthew, Alexander C. 3 Canal-terrace, Aberdeen.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
*Matthews, Henry, F.C.S. 60 Gower-street, London, W.C.
1860. §Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1855. ‡Maule, Rev. Thomas, M.A. Partick, near Glasgow.
1865. *Maw, George, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1864. *Maxwell, Francis. Speddock, near Dumfries.
*Maxwell, James Clerk, M.A., LL.D., F.R.S., L. & E. Professor of Experimental Physics in the University of Cambridge. Glenlair, Dalbeattie, N.B.
1852. ‡*Maxwell, John Waring. Finnebrogue, Downpatrick, Ireland.*
*Maxwell, Robert Perceval. Groomsport House, Belfast.
1865. *May, Walter. Elmley Lodge, Harborne, Birmingham.
1868. §Mayall, J. E. Hove-place House, Brighton.
*Mayne, Rev. Charles, M.R.I.A. Killaloe, Co. Clare, Ireland.
1857. ‡*Mayne, William Annesley.*
1863. §Mease, George D. Bylton Villa, South Shields.
1863. ‡Mease, Solomon. Cleveland House, North Shields.
‡Meath, Samuel Butcher, D.D., Lord Bishop of. Ardbraccan, Co. Meath.
1861. ‡Medcalf, William. 20 Bridgewater-place, Manchester.
1867. ‡Meldrum, Charles. Mauritius.
1866. ‡Mello, Rev. J. M. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1862. §Mennell, Henry J. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1868. §Merrifield, Charles W., F.R.S., Principal of the Royal School of Naval Architecture, Superintendent of the Naval Museum at South Kensington, Hon. Sec. I.N.A. 23 Scarsdale-villas, Kensington, London, S.W.
1863. §Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. §Miall, Louis C. Bradford, Yorkshire.
1847. *Michell, Rev. Richard, D.D., Principal of Magdalen Hall, Oxford.
1865. ‡Michie, Alexander. 26 Austin Friars, London, E.C.
1865. §Middlemore, William. Edgbaston, Birmingham.
1866. ‡Midgley, John. Colne, Lancashire.

Year of
Election.

1867. ‡Midgley, Robert. Colne, Lancashire.
1855. ‡Miles, Rev. Charles P., M.D. 58 Brompton-crescent, London, S.W.
1857. ‡*Millar, George M.*
1859. ‡Millar, John. Lisburn, Ireland.
1863. §Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London, N.E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1859. ‡Miller, James, jun. Greenock.
1865. ‡Miller, Rev. J. C., D.D. The Vicarage, Greenwich, London, S.E.
*Miller, Patrick, M.D. The Grove, Mount Radford, Exeter.
1861. *Miller, Robert. Whalley Range, Manchester.
1863. ‡*Miller, Thomas. Righill Hall, Durham.*
Miller, William Hallows, M.A., LL.D., For. Sec. R.S., F.G.S., Professor of Mineralogy in the University of Cambridge. 7 Scroope-terrace, Cambridge.
1868. *Milligan, Joseph, F.L.S., F.G.S., F.R.A.S., F.R.G.S.. 15 Northumberland-street, Strand, London, W.C.
1842. Milligan, Robert. Acacia in Randon, Leeds.
1868. §Mills, Edmund J. 12 Pemberton-terrace, St. John's Wood Park, London, N.W.
*Mills, John Robert. Bootham, York.
1867. ‡Milne, James. Murie House, Errol, by Dundee.
Milne, Rear-Admiral Sir Alexander, K.C.B., F.R.S.E. Musselborough, Edinburgh.
*Milne-Home, David, M.A., F.R.S.E., F.G.S. Paxton House, Berwick, N.B.
1854. *Milner, William. Phœnix Safe Works, Liverpool.
1864. *Milton, The Right Hon. Lord, M.P., F.R.G.S. 17 Grosvenor-street, London, W.; and Wentworth, Yorkshire.
1865. ‡Minton, Samuel, F.G.S. Oakham House, near Dudley.
1855. ‡Mirrlees, James Buchanan. 128 West-street, Tradeston, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1863. ‡Mitchell, C. Walker, Newcastle-on-Tyne.
1855. ‡*Mitchell, George. Glasgow.*
1870. §Mitchell, John. York House, Clitheroe.
1868. §Mitchell, John, jun. Pole Park House, Dundee.
1862. *Mitchell, William Stephen, LL.B., F.L.S., F.G.S. Caius College, Cambridge.
1855. *Moffat, John, C.E. Ardrossan, Scotland.
1854. §Moffat, Thomas, M.D., F.G.S., F.R.A.S., F.M.S. Hawarden, Chester.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1866. §Moggridge, Matthew, F.G.S. 3 Park-villas, Richmond, Surrey.
1855. §Moir, James. 174 Gallogate, Glasgow.
1861. ‡Molesworth, Rev. W. N., M.A. Spotland, Rochdale.
Mollan, John, M.D. 8 Fitzwilliam-square North, Dublin.
1852. ‡Molony, William, LL.D. Carrickfergus.
1865. §Molyneux, William, F.G.S. Manor House, Burton-upon-Trent.
1853. ‡Monday, William, Hon. Sec. Hull Lit. and Phil. Soc. 6 Jarratt-street, Hull.
1860. §Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Higham, Ferrers, Northamptonshire.
1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1857. §Moore, Arthur. Cradley House, Clifton, Bristol.
1859. §Moore, Charles, F.G.S. 6 Cambridge-terrace, Bath.
1857. ‡Moore, Rev. John, D.D. Clontarf, Dublin.
Moore, John. 2 Meridian-place, Clifton, Bristol.

Year of Election.

*Moore, John Carrick, M.A., F.R.S., F.G.S. 113 Eaton-street, London, S.W.; and Corswall, Wigtonshire.
1866. *Moore, Thomas, F.L.S. Botanic Gardens, Chelsea, London, S.W.
1854. ‡Moore, Thomas John, Cor.M.Z.S. Free Public Museum, Liverpool.
1835. Moore, William D., M.D. 40 Fitzwilliam-square West, Dublin.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1861. ‡Morewood, Edmund. Cheam, Surrey.
Morgan, Captain Evan, R.A.
1868. ‡Morgan, Thomas H. Oakhurst, Hastings.
1849. ‡Morgan, William. 37 Waterloo-street, Birmingham.
Morley, George. Park-place, Leeds.
1863. ‡Morley, Samuel, M.P. Lenton-grove, Nottingham.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.
1861. *Morris, David. Royal Exchange, Manchester.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1861. ‡Morris, William. The Grange, Salford.
1867. §Morrison, William R. Dundee.
1863. ‡Morrow, R. J. Bentick Villas, Newcastle-on-Tyne.
1865. §Mortimer, J. R. Fimber, Malton.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §Morton, George H., F.G.S. 21 West Derby-street, Liverpool.
1858. *Morton, Henry Joseph. Garforth House, West Garforth, near Leeds.
1847. ‡Moseley, Rev. Henry, M.A., F.R.S. Olveston Vicarage, near Bristol.
1868. ‡Moseley, H. N. Olveston, Bristol.
1857. ‡Moses, Marcus. 4 Westmoreland-street, Dublin.
1862. ‡*Mosheimer, Joseph.*
Mosley, Sir Oswald, Bart., D.C.L., F.L.S., F.G.S. Rolleston Hall, Burton-upon-Trent, Staffordshire.
Moss, John. Otterspool, near Liverpool.
1870. §Moss, John Miles. Springbank, Waterloo, Liverpool.
1853. *Moss, William Henry. Kingston-terrace, Hull.
1864. §Mosse, J. R. (H. S. King & Co., 65 Cornhill, London, E.C.) General Manager's Office, Mauritius Railway, Port Louis, Mauritius.
1869. §Mott, A. J. Sandfield, Waterloo, Liverpool.
1865. §Mott, Charles Grey. The Park, Birkenhead.
1866. §Mott, Frederick. 1 De Montfort-street, Leicester.
1862. *Mouat, Frederick John, M.D., Inspector-General of Prisons, Bengal.
1856. ‡Mould, Rev. J. G., B.D. 21 Camden-crescent, Bath.
1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.
1861. *Mountcastle, William Robert. 7 Market-street, Manchester.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, J. T. 27 Dundas-street, Edinburgh.
1855. ‡Muir, William. 10 St. John-street, Adelphi, London, W.C.
Muirhead, James. 90 Buchanan-street, Glasgow.
1857. ‡Mullins, M. Bernard, M.A., C.E. 1 Fitzwilliam-square South, Dublin.
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡Mundella, A. J., M.P., F.R.G.S. The Park, Nottingham.
1864. *Munro, Major-General William, C.B., F.L.S. United Service Club, Pall Mall, London, S.W.; and Mapperton Lodge, Farnborough, Hants.
1864. §Murch, Jerom. Cranwells, Bath.
*Murchison, John Henry, F.G.S. Surbiton-hill, Kingston.
1864. *Murchison, K. R. 10 Victoria-park, Dover.

Year of Election.

*Murchison, Sir Roderick Impey, Bart., K.C.B., M.A., D.C.L. Oxon., LL.D. Camb., F.R.S., F.G.S., F.R.G.S., Hon. Mem. R.S.Ed. & R.I.A., Director-General of the Geological Survey of the United Kingdom. 16 Belgrave-square, London, S.W.
1864. ‡Murchison, Captain R. M. Caerbaden House, Cleveland-walk, Bath.
1855. ‡Murdock, James B. 195 Bath-street, Glasgow.
1858. ‡Murgatroyd, William. Bank Field, Bingley.
Murley, Rev. C. H. South Petherton, Ilminster.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1869. §Murray, Adam. 4 Westbourne-crescent, Hyde Park, London, W.
1850. ‡Murray, Andrew, F.L.S. 67 Bedford Gardens, Kensington, London, W.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, C.E. 11 Great Queen-street, Westminster, S.W.
‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
*Murton, James. Silverdale, near Carnforth, Lancaster.
Musgrave, The Venerable Charles, D.D., Archdeacon of Craven. Halifax.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
*Muspratt, James Sheridan, M.D., Ph.D., F.C.S. College of Chemistry, Liverpool.
1865. ‡Myers, Rev. E., F.G.S. 17 Summerhill-terrace, Birmingham.
1859. §Mylne, Robert William, F.R.S., F.G.S., F.S.A. 21 Whitehall-place, London, S.W.
1850. ‡Myrtle, J. Y., M.D. 113 Princes-street, Edinburgh.

1850. ‡Nachot, H. W., Ph.D. 59 George-street, Edinburgh.
1842. Nadin, Joseph. Manchester.
1855. *Napier, James R., F.R.S. 22 Blythwood-square, Glasgow.
1839. *Napier, Right Hon. Sir Joseph, Bart. 4 Merrion-square, Dublin.
*Napier, Captain Johnstone. Tavistock House, Salisbury.
1855. ‡Napier, Robert. West Chandon, Gareloch, Glasgow.
Napper, James William L. Loughcrew, Oldcastle., Co. Meath.
1866. ‡Nash, Davyd W., F.S.A., F.L.S. 10 Imperial-square, Cheltenham.
1850. *Nasmyth, James. Penshurst, Tunbridge.
1864. ‡Natal, William Colenso, Lord Bishop of.
1860. ‡Neate, Charles, M.A. Oriel College, Oxford.
1867. §Neaves, The Right Hon. Lord. 7 Charlotte-square, Edinburgh.
1845. ‡*Neild, Arthur. Ollernshaw, Whaleybridge, by Stockport.*
1853. ‡Neill, William, Governor of Hull Jail. Hull.
Neilson, Robert.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1865. ‡Neilson, W. Montgomerie. Glasgow.
Ness, John. Helmsley, near York.
1868. ‡Nevill, Rev. H. R. Great Yarmouth.
1866. *Nevill, Rev. Samuel Tarratt, B.A., F.L.S. Shelton Rectory, near Stoke-upon-Trent.
1861. ‡Nevill, Thomas Henry. 17 George-street, Manchester.
1857. ‡Neville, John, C.E., M.R.I.A. Dundalk, Ireland.
1852. ‡Neville, Parke, C.E. Town Hall, Dublin.
1869. §Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.

Year of
Election.

Newall, Henry. Hare-hill, Littleborough, Lancashire.
*Newall, Robert Stirling. Ferndene, Gateshead-upon-Tyne.
1867. §Newbegin, James. Norwich.
1866. *Newdegate, Albert L. 14 Dover-street, Piccadilly, London, W.
1854. *Newlands, James, C.E. 88 Chatham-street, Abercromby-square, Liverpool.
1842. *Newman, Professor Francis William. 1 Dover-place, Clifton, Bristol.
*Newman, William. Darley Hall, near Barnsley, Yorkshire.
1863. *Newmarch, William, F.R.S. Heath View, West-side, Clapham Common, London, S.W.
1866. *Newmarch, William Thomas. 4 Huntington-place, Tynemouth.
1858. ‡*Newsome, Thomas. Park-road, Leeds.*
1860. *Newton, Alfred, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge. Magdalen College, Cambridge.
1865. ‡Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon.
1867. ‡Nicholl, Dean of Guild. Dundee.
Nicholl, Iltyd, F.L.S. Uske, Monmouthshire.
1848. ‡Nicholl, W. H. The Ham, Cowbridge, Glamorganshire.
1866. §Nicholson, Sir Charles, Bart., D.C.L., LL.D., M.D., F.G.S., F.R.G.S. 26 Devonshire Place, Portland-place, London, W.
*Nicholson, Cornelius, F.G.S. Welfield, Muswell-hill, London, N.
1861. *Nicholson, Edward. 88 Mosley-street, Manchester.
1867. ‡Nicholson, Henry Alleyne, D.Sc., F.G.S. Newhaven Park, Newhaven, near Edinburgh.
*Nicholson, John A., A.M., M.B., Lic. Med., M.R.I.A. Balrath Burry, Kells, Co. Meath.
1850. ‡Nicol, James, F.R.S.E., F.G.S., Professor of Natural History in Marischal College, Aberdeen.
1851. ‡*Nicolay, Rev. C. G. King's College, London.*
1867. ‡Nimmo, Dr. Matthew, L.R.C.S.E. Nethergate, Dundee.
Niven, Ninian. Clonturk Lodge, Drumcondra, Dublin.
1864. ‡Noad, Henry M., Ph.D., F.R.S., F.C.S. 72 Hereford-road, Bayswater, London, W.
1863. *Noble, Captain William R. Elswick Works, Newcastle-on-Tyne.
1870. §Nolan, Joseph. 14 Hume-street, Dublin.
1860. *Nolloth, Matthew S., Captain R.N., F.R.G.S. United Service Club, S.W.; and 13 North-terrace, Camberwell, London, S.E.
1859. ‡Norfolk, Richard. Messrs. W. Rutherford and Co., 14 Canada Dock, Liverpool.
1868. ‡Norgate, William. Newmarket-road, Norwich.
1863. §Norman, Rev. Alfred Merle, M.A. Houghton-le-Spring, Co. Durham.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
Norris, Charles. St. John's House, Halifax.
1865. ‡Norris, Richard, M.D. 2 Walsall-road, Birchfield, Birmingham.
1866. ‡North, Thomas. Cinder Hill, Nottingham.
Northampton, Charles Douglas, The Right Hon. Marquis of. 145 Piccadilly, London, W.; and Castle Ashby, Northamptonshire.
1869. §Northcote, Right Hon. Sir Stafford H., Bart., C.B., M.P. Pynes, Exeter; and 42 Harley-street, London, W.
*Northwick, The Right Hon. Lord, M.A. 22 Park-street, Grosvenor-square, London, W.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of Norwich.

Year of Election.

1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.
1869. §Noyes, H. C. Victoria-terrace, Heavitree, Exeter.
1859. ‡Nuttall, James. Wellfield House, Todmorden.

O'Beirne, James, M.D. 11 Lower Gardiner-street, Dublin.
O'Brien, Baron Lucius. Dromoland, Newmarket-on-Fergus, Ireland.
O'Callaghan, George. Tallas, Co. Clare.
1858. *O'Callaghan, Patrick, LL.D., D.C.L. 16 Clarendon-square, Leamington.
Odgers, Rev. William James. Sion-hill, Bath.
1858. *Odling, William, M.B., F.R.S., F.C.S., Fullerian Professor of Chemistry in the Royal Institution, London. Sydenham-road, Croydon, Surrey.
1857. ‡O'Donnavan, William John. Portarlington, Ireland.
1870. §O'Donnell, J. O., M.D. 34 Rodney-street, Liverpool.
1866. ‡Ogden, James. Woodhouse, Loughborough.
1859. ‡Ogilvie, C. W. Norman. Baldovan House, Dundee.
*Ogilvie, George, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. 29 Union-place, Aberdeen.
1863. ‡Ogilvy, G. R. Inverquharity, N.B.
1863. ‡Ogilvy, Sir John, Bart. Inverquharity, N. B.
1863. ‡*Ogle, Rev. E. C.*
*Ogle, William, M.D., M.A. 98 Friar Gate, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. ‡O'Hagan, John. 20 Kildare-street, Dublin.
1862. ‡O'Kelly, Joseph, M.A. 51 Stephen's Green, Dublin.
1857. ‡O'Kelly, Matthias J. Dalkey, Ireland.
1853. §Oldham, James, C.E. Austrian Chambers, Hull.
1857. *Oldham, Thomas, M.A., LL.D., F.R.S., F.G.S., M.R.I.A., Director of the Geological Survey of India. 1 Hastings-street, Calcutta.
1860. ‡O'Leary, Professor Purcell, M.A. Sydney-place, Cork.
1863. ‡*Oliver, D. Royal Gardens, Kew.*
*Ommanney, Erasmus, Rear-Admiral, C.B., F.R.S., F.R.A.S., F.R.G.S. 6 Talbot-square, Hyde-park, London, W.; and United Service Club, Pall Mall, London, S.W.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1842. Ormerod, George Wareing, M.A., F.G.S. Brookbank, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham-hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
Orpen, John H., LL.D., M.R.I.A. 58 Stephen's Green, Dublin.
1854. ‡Orr, Sir Andrew. Blythwood-square, Glasgow.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*Osler, A. Follett, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. South Bank, Edgbaston, Birmingham.
1854. §Outram, Thomas. Greetland, near Halifax.
Overstone, Samuel Jones Lloyd, Lord, F.G.S. 22 Norfolk-street, Park-lane, London, W.; and Wickham Park, Bromley.
1870. §Owen, Harold. Tue Brook Villa, Liverpool.
1857. ‡Owen, James H. Park House, Sandymount, Co. Dublin.
Owen, Richard, M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. M.R.S.E., Director of the Natural History Department, British Museum. Sheen Lodge, Mortlake, Surrey, S.W.
1863. *Ower, Charles, C.E. 11 Craigie-terrace, Dundee.
1869. *Owst-Atkinson, A., M.A. Quay Chambers, Hull; and New University Club, London, S.W.

Year of Election.

1859. ‡Page, David, LL.D., F.R.S.E., F.G.S. 44 Gilmore-place, Edinburgh.
1863. ‡Paget, Charles. Ruddington Grange, near Nottingham.
1870. §Palgrave, R. H. Inglis. 11 Britannia-terrace, Great Yarmouth.
1863. ‡Palmer, C. M. Whitley Park, near Newcastle-on-Tyne.
1866. §Palmer, H. 76 Goldsmith-street, Nottingham.
**Palmer, Sir William, Bart.*
1866. §Palmer, William. Iron Foundry, Canal-street, Nottingham.
Palmes, Rev. William Lindsay, M.A. The Vicarage, Hornsea, Hull.
1854. ‡Pare, William, F.S.S. Seville Iron Works, Dublin.
1857. *Parker, Alexander, M.R.I.A.. William-street, Dublin.
1863. ‡Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
Parker, Joseph, F.G.S. Upton Chaney, Bitton, near Bristol.
Parker, Richard. Dunscombe, Cork.
Parker, Rev. William. Saham, Norfolk.
1865. *Parker, Walter Mantel. Warren-corner House, near Farnham, Surrey.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1861. ‡*Parkes, Alexander.*
1865. *Parkes, Samuel Hickling. 5 St. Mary's-row, Birmingham.
1864. §Parkes, William. 14 Park-street, Westminster, S.W.
1859. ‡Parkinson, Robert, Ph.D. Bradford, Yorkshire.
1863. ‡Parland, Captain. Stokes Hall, Jesmond, Newcastle-on-Tyne.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, N.E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N. B.
Partington, James Edge.
Partridge, Richard, F.R.S., Professor of Anatomy to the Royal Academy of Arts, and to King's College, London. 17 New-street, Spring-gardens, London, S.W.
1865. *Parsons, Charles Thomas. 8 Portland-road, Edgbaston, Birmingham.
1855. ‡Paterson, William. 100 Brunswick-street, Glasgow.
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1839. *Patterson, Robert, F.R.S. 59 High-street, Belfast.
1863. ‡Pattinson, John. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-on-Tyne.
1867. ‡Pattison, Samuel R., F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1863. §Paul, Benjamin H., Ph.D. 1 Victoria-street, Westminster, S.W.
1863. ‡Pavy, Frederick William, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.
1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.
1851. ‡Payne, Joseph. 4 Kildare Gardens, Bayswater, London, W.
1866. §Payne, Dr. Joseph F. 4 Kildare-gardens, Bayswater, London, W.
1847. §Peach, Charles W. 30 Haddington-place, Leith-walk, Edinburgh.
1868. ‡Peacock, Ebenezer. 32 University-street, London, W.C.
1863. §Peacock, Richard Atkinson. St. Heliers, Jersey.
*Pearsall, Thomas John, F.C.S. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, E.C.
Pearson, Charles. 10 Torrington-square, London, W.C.
1853. ‡*Pearson, Robert H. 1 Prospect House, Hull.*
1870. §Pearson, Rev. Samuel. 3 Greenheys-road, Prince's-park, Liverpool.
Pearson, Rev. Thomas, M.A.
1863. §Pease, H. F. Brinkburn, Darlington.

Year of Election.

1852. ‡Pease, Joseph Robinson. Hesslewood.
1863. *Pease, Joseph W., M.P. Hutton Hall, Guisborough.
1863. ‡Pease, J. W. Newcastle-on-Tyne.
1858. *Pease, Thomas, F.G.S. Cote Bank, Westbury-on-Trym, near Bristol.
Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.
1855. *Peckover, Alexander, F.R.G.S. Wisbeach, Cambridgeshire.
*Peckover, Algernon, F.L.S. Harecroft House, Wisbeach, Cambridgeshire.
*Peckover, William, F.S.A. Wisbeach, Cambridgeshire.
*Peel, George. Soho Iron Works, Manchester.
1861. *Peile, George, jun. Shotley Bridge, Co. Durham.
1861. *Peiser, John. Barnfield House, 491 Oxford-street, Manchester.
1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.
1861. *Pender, John. Mount-street, Manchester.
1868. §Pendergast, Thomas. Lancefield, Cheltenham.
1856. §Pengelly, William, F.R.S., F.G.S. Lamorna, Torquay.
1845. ‡Percy, John, M.D., F.R.S., F.G.S., Professor of Metallurgy in the Government School of Mines. Museum of Practical Geology, Jermyn-street, S.W.; and 1 Gloucester-crescent, Hyde-park, London.
1868. *Perkin, William Henry, F.R.S., F.C.S. Seymour Villa, Sudbury, N.W.
1861. ‡Perkins, Rev. George. St. James's View, Dickenson-road, Rusholme, near Manchester.
Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.
1864. *Perkins, V. R. Wotton-under-Edge, Gloucestershire.
1867. ‡Perkins, William. 6 Russell-place, Fitzroy-square, London, W.
1861. ‡Perring, John Shae. 104 King-street, Manchester.
Perry, The Right Rev. Charles, M.A., Bishop of Melbourne, Australia.
*Perry, Rev. S. G. F., M.A. Tottington Parsonage, near Bury.
1870. §Perry, Rev. S. J. Stonyhurst College Observatory, Whalley, Blackburn.
1861. *Petrie, John. South-street, Rochdale.
Pett, Samuel, F.G.S. 7 Albert-road, Regent's Park, London, N.W.
Peyton, Abel. Oakhurst, Edgbaston, Birmingham.
1867. ‡Phayre, Colonel Sir Arthur. East India United Service Club, St. James's Square, London, S.W.
1857. ‡*Phayre, George.*
1845. ‡Phelps, Rev. Robert, D.D. Cambridge.
1863. *Phené, John Samuel, F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, Chelsea, London, S.W.
1870. §Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. 35 Church-street, Manchester.
*Philips, Mark. Snitterfield, Stratford-on-Avon.
Philips, Rob. N. The Park, Manchester.
1863. ‡Philipson, Dr. 1 Saville Row, Newcastle-on-Tyne.
1856. *Phillipps, Sir Thomas, Bart., M.A., F.R.S., F.G.S. Thirlestaine House, Cheltenham.
1859. *Phillips, Major-General Sir Frowell. 1 Vere-street, Cavendish-square, London, W.
1862. ‡Phillips, Rev. George, D.D., Queen's College, Cambridge.
1870. §Phillips, J. Arthur. Cressington-park, Aigburth, Liverpool.
*Phillips, John, M.A., LL.D., D.C.L., F.R.S., F.G.S., Professor of Geology in the University of Oxford. Museum House, Oxford.
1859. ‡*Phillips, Major J. Scott.*
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡Phipson, T. L., Ph.D. 4 The Cedars, Putney, Surrey.

Year of Election.

1864. ‡Pickering, William. Oak View, Clevedon.
1861. ‡Pickstone, William. Radcliff Bridge, near Manchester.
1870. §Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1856. ‡Pierson, Charles. 3 Blenheim-parade, Cheltenham.
1870. §Pigot, Rev. E. V. Malpas, Cheshire.
Pigott, J. H. Smith.
1865. ‡Pike, L. Owen. 25 Carlton-villas, Maida Vale, London, W.
*Pike, Ebenezer. Besborough, Cork.
1864. ‡*Pilditch, Thomas. Portway House, Frome.*
1857. ‡Pilkington, Henry M., M.A., Q.C. 35 Gardiner's-place, Dublin.
1863. *Pim, Captain Bedford C. T., R.N., F.R.G.S. 11 Belsize-square, Hampstead, London, N.W.
Pim, George, M.R.I.A. Brennan's Town, Cabinteely, Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
Pim, William H. Monkstown, Dublin.
1861. ‡Pincoffs, Simon. Crumpsall Lodge, Cheetham-hill, Manchester.
1868. ‡Pinder, T. R. St. Andrews, Norwich.
1859. ‡Pirrie, William, M.D. 238 Union-street West, Aberdeen.
1866. ‡Pitcairn, David. Dudhope House, Dundee.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1869. §Plant, James. Leicester.
1865. ‡Plant, Thomas L. Camp-hill, and 33 Union-street, Birmingham.
1863. *Platt, John, M.P. Werneth Park, Oldham, Lancashire.
1867. ‡Playfair, Lieut.-Colonel, H.M. Consul, Algeria.
1842. Playfair, Lyon, C.B., Ph.D., LL.D., M.P., F.R.S. L. & E., F.C.S. 4 Queensberry Place, South Kensington, London, S.W.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *Pochin, Henry Davis, M.P., F.C.S. Broughton Old Hall, Manchester.
1846. ‡Pole, William, Mus. Doc., F.R.S. The Athenæum Club, Pall Mall, London,,S.W.
*Pollexfen, Rev. John Hutton, M.A., Rector of St. Runwald's. 6 St. Mary's-terrace, Colchester.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1854. ‡Poole, Braithwaite. Birkenhead.
1868. ‡Pooley, Thomas A., B.Sc. South Side, Clapham-common, London, S.W.
1868. ‡Portal, Wyndham S. Malsanger, Basingstoke.
Porter, Rev. Charles, D.D.
*Porter, Henry J. Ker, M.R.I.A. 91 Dean-street, Soho, London, W.
1866. §Porter, R. Beeston, Nottingham.
Porter, Rev. T. H., D.D. Desertcreat, Co. Armagh.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*Potter, Edmund, M.P., F.R.S. Camfield-place, Hatfield, Herts.
1842. Potter, Thomas. George-street, Manchester.
Potter, William.
1863. ‡Potts, James. 52½ Quayside, Newcastle-on-Tyne.
1857. *Pounden, Captain Londsdale, F.R.G.S. Junior United Service Club, St. James's-sq., London, S.W.; and Brownswood, Co. Wexford
1857. ‡Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1867. ‡Powrie, James. Reswallie, Forfar.
1859. ‡*Poynter, John. Glasgow.*
1855. *Poynter, John E. Clyde Neuck, Uddingstone, Hamilton, Scotland.
1864. ‡Prangley, Arthur. 2 Burlington-buildings, Redland, Bristol.
Pratt, Archdeacon, M.A., F.C.P.S. Calcutta.
1869. *Preece, William Henry. Grosvenor House, Southampton.
1864. *Prentice, Manning. Violet Hill, Stowmarket, Suffolk.

Year of Election.

Prest, The Venerable Archdeacon Edward. The College, Durham.
Prest, John. Blossom-street, York.
*Prestwich, Joseph, F.R.S., Pres. G.S. 69 Mark-lane, London, E.C.; and Shoreham, near Sevenoaks.
1856. *Price, Rev. Bartholomew, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford. 11 St. Giles's-street, Oxford.
1870. §Price, Captain E. W., M.P. Tibberton Court, Gloucestershire.
Price, J. T. Neath Abbey, Glamorganshire.
1865. ‡Prideaux, J. Symes. 209 Piccadilly, London, W.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1865. *Prichard, Thomas, M.D. Abington Abbey, Northampton.
1835. *Pritchard, Andrew. 87 St. Paul's-road, Canonbury, London, N.
1846. *Pritchard, Rev. Charles, M.A., F.R.S., F.R.A.S., F.G.S., Professor of Astronomy, Oxford.
1863. ‡Procter, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, Thomas. Elmsdale House, Clifton Down, Bristol.
Proctor, William. 108 Pembroke-road, Clifton, Bristol.
1858. §Proctor, William, M.D., F.C.S. 24 Petergate, York.
1863. *Prosser, Thomas. West Boldon, Co. Durham.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1865. §Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
1864. ‡Pugh, John. Aberdovey, Shrewsbury.
1859. ‡Pugh, William. Coalport, Shropshire.
1867. ‡Pullar, John. 4 Leonard Bank, Perth.
1867. §Pullar, Robert. 6 Leonard Bank, Perth.
1842. *Pumphrey, Charles. 33 Frederick-street, Edgbaston, Birmingham.
Punnett, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
1869. ‡Purchas, Rev. W. H. St. James's, Gloucester.
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡Purdy, Frederick, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.
1866. ‡Purser, John. Queen's College, Belfast.
1860. *Pusey, S. E. Bouverie. 7 Green-street, London, W.; and Pusey, Farringdon.
1861. *Pyne, Joseph John. Hope House, Heald Grove, Rusholme, Manchester.
1868. §Pye-Smith, P. H., M.D. Finsbury-square, E.C., and Guy's Hospital, London, S.E.

1870. §Rabbits, W. T. Forest-hill, London, S.E.
1860. ‡Radcliffe, Charles Bland, M.D. 4 Henrietta-street, Cavendish-square, London, W.
1870. §Radcliffe, D. R. Phœnix Safe-works, Windsor, Liverpool.
*Radford, William, M.D. Sidmount, Sidmouth.
1861. ‡Rafferty, Thomas. 13 Monmouth-terrace, Rusholme, Manchester.
1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1870. §Raffles, William Winter. Sunnyside, Prince's-park, Liverpool.
1859. ‡Rainey, George, M.D. 17 Golden-square, Aberdeen.
1855. ‡Rainey, Harry, M.D. 10 Moore-place, Glasgow.
1864. ‡Rainey, James T. 8 Widcomb-crescent, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. §Ramsay, Alexander, jun., F.G.S. 45 Norland-square, Notting Hill, London, W.

Year of
Election.

1845. ‡Ramsay, Andrew Crombie, LL.D., F.R.S., F.G.S., Director of the Geological Survey of Great Britain, Professor of Geology in the Royal School of Mines. Museum of Practical Geology, Jermyn-street, London, S.W.
1863. ‡Ramsay, D. R. Wallsend, Newcastle-on-Tyne.
1867. ‡Ramsay, James, Jun. Dundee.
1861. ‡Ramsay, John. Kildalton, Argyleshire.
1867. *Ramsay, W. F., M.D. 15 Somerset-street, Portman-square, London, W.
1835. *Rance, Henry (Solicitor). Cambridge.
1869. *Rance, H. W. Henniker. Cambridge.
Rand, John. Wheatley-hill, Bradford, Yorkshire.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
1860. ‡Randall, Thomas. Grandepoint House, Oxford.
1855. ‡Randolph, Charles. Pollockshiels, Glasgow.
1860. *Randolph, Rev. Herbert, M.A. Marcham, near Abingdon.
Ranelagh, the Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.
1850. §Rankine, William John Macquorn, LL.D., F.R.S. L. & E., Regius Professor of Civil Engineering and Mechanics in the University of Glasgow. 59 St. Vincent-street, Glasgow.
1861. §Ransome, Arthur, M.A. Bowdon, Manchester.
Ransome, Thomas. 34 Princess-street, Manchester.
1863. §Ransom, William Henry, M.D., F.R.S. Low Pavement, Nottingham.
1868. *Ranson, Edwin. Kempstone, near Bedford.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
1868. ‡Rassam, Hormuzed.
*Ratcliff, Colonel Charles, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.
1864. §Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. §Rathbone, Benson. Exchange-buildings, Liverpool.
1870. §Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.
1870. §Rathbone, R. R. 11 Rumford-street, Liverpool.
1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.
Rawdon, William Frederick M.D. Bootham, York.
1870. §Rawlins, G. W. The Hollies, Rainhill, Liverpool.
*Rawlins, John. Llewesog Hall, near Denbigh.
1866. *Rawlinson, George, M.A., Camden Professor of Ancient History in the University of Oxford. 53 Broad-street, Oxford.
1855. *Rawlinson, Major-General Sir Henry C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
Rawson, Rawson William, F.R.G.S.
1865. §Rayner, Henry. Liverpool-road, Chester.
1870. §Rayner, Joseph (Town Clerk). Liverpool.
1852. ‡Read, Thomas, M.D. Donegal-square West, Belfast.
1865. ‡Read, William. Albion House, Epworth, Bawtry.
*Read, W. H. Rudstone, M.A., F.L.S. Blake-street, York.
1870. §Reade, Thomas M. Blundell Sands, Liverpool.
1862. *Readwin, Thomas Allison, F.G.S. 12 Wynne-road, Brixton-road, London, S.W.
1852. *Redfern, Professor Peter, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1863. ‡Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. *Reé, H. P. 27 Faulkner-street, Manchester.

Year of
Election.

1861. ‡Reed, Edward J., Vice-President of the Institute of Naval Architects. Chorlton-street, Manchester.
1869. ‡Reid, J. Wyatt. 40 Great Western-terrace, Bayswater, London, W.
1850. ‡Reid, William, M.D. Cuivie, Cupar, Fife.
1863. §Renals, E. 'Nottingham Express' Office, Nottingham.
1863. ‡Rendel, G. Benwell, Newcastle-on-Tyne.
Rennie, Sir John, Knt., F.R.S., F.G.S., F.S.A., F.R.G.S. 7 Lowndes-square, London, S.W.
1860. ‡Rennison, Rev. Thomas, M.A. Queen's College, Oxford.
*_Renny, Lieutenant H. L., R.E. Montreal._
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1869. ‡Révy, J. J. 16 Great George-street, Westminster, S.W.
1870. *Reynolds, Osborne, Professor of Engineering in Owens College, Manchester.
1858. §Reynolds, Richard, F.C.S. 13 Briggate, Leeds.
Reynolds, William, M.D. Coeddu, near Mold, Flintshire.
1850. ‡Rhind, William. 121 Princes-street, Edinburgh.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1868. §Richards, Rear-Admiral George H., F.R.S., F.R.G.S., Hydrographer to the Admiralty. The Admiralty, Whitehall, London, S.W.
1863. §Richardson, Benjamin Ward, M.A., M.D., F.R.S. 12 Hinde-street, Manchester-square, London, W.
1861. §Richardson, Charles. Almondbury, Bristol.
1869. *Richardson, Charles. West End, Abingdon, Berks.
1863. *Richardson, Edward, jun. 3 Lovaine-place, Newcastle-on-Tyne.
1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1870. §Richardson, J. H. 3 Arundel-terrace, Cork.
1868. §Richardson, James C. Glanrafon, near Swansea.
1863. ‡Richardson, John W. South Ashfield, Newcastle-on-Tyne.
1870. §Richardson, Ralph. 16 Coates-crescent, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
Richardson, William. Micklegate, York.
1861. §Richardson, William. 4 Edward-street, Werneth, Oldham.
1861. ‡Richson, Rev. Canon, M.A. Shakespeare-street, Ardwick, Manchester.
1863. ‡Richter, Otto, Ph.D. 7 India-street, Edinburgh.
1870. §Rickards, Dr. 36 Upper Parliament-street, Liverpool.
1868. §Ricketts, Charles, M.D., F.G.S. 22 Argyle-street, Birkenhead.
*Riddell, Major-General Charles J. Buchanan, C.B., F.R.S. Athenæum Club, Pall Mall, London, S.W.
1861. *Riddell, H. B. Whitefield House, Rothbury, Morpeth.
1859. ‡Riddell, Rev. John. Moffat by Beatlock, N. B.
1861. *Rideout, William J. 51 Charles-street, Berkeley-square, London, W.
1862. ‡Ridgway, Henry Akroyd, B.A. Bank Field, Halifax.
1861. §Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1863. ‡Ridley, Samuel. 7 Regent's-terrace, Newcastle-on-Tyne.
1863. *Rigby, Samuel. Bruche Hall, Warrington.
*_Rinder, Miss._
1860. ‡Ritchie, George Robert. 4 Watkyn-Terrace, Coldharbour-lane, Camberwell, London.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert, C.E. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1853. ‡Rivay, John V. C. 19 Cowley-street, London, S.W.
1869. *Rivington, John. 14 Porchester-terrace, Hyde Park, London, W.
1854. ‡Robberds, Rev. John, B.A. Ashlar House, Battledown, Cheltenham.
1869. *Robbins, J. 372 Oxford-street, London, W.
1855. ‡Roberton, James. Gorbals Foundry, Glasgow.

Year of Election.

Roberton, John. Oxford-road, Manchester.
1859. ‡Roberts, George Christopher. Hull.
1859. ‡Roberts, Henry, F.S.A. Athenæum Club, London, S.W.
1870. *Roberts, Isaac. 26 Rock-park, Rock Ferry, Cheshire.
1857. ‡Roberts, Michael, M.A. Trinity College, Dublin.
*Roberts, William P. 38 Red Lion-square, London, W.C.
1868. §Roberts, W. Chandler, F.G.S., F.C.S. Royal Mint, London, E.C.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1866. §Robertson, Alister Stuart, M.D., F.R.G.S. Horwich, Bolton, Lancashire.
1867. §Robertson, David. Union Grove, Dundee.
1870. *Robertson, John. Oxford-road, Manchester.
1866. ‡Robertson, William Tindal, M.D. Nottingham.
1863. ‡*Robinson, Dr.*
1861. §Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Tartaragham Glebe, Loughgall, Ireland.
1864. ‡*Robinson, George Augustus.*
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
1860. ‡*Robinson, Professor H. D.*
*Robinson, H. Oliver. 194 West George-street, Glasgow.
1866. ‡Robinson, John. Museum, Oxford.
1861. ‡Robinson, John. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.
1855. ‡Robinson, M. E. 116 St. Vincent-street, Glasgow.
1860. ‡Robinson, Admiral Robert Spencer. 61 Eaton-place, London, S.W.
Robinson, Rev. Thomas Romney, D.D., F.R.S., F.R.A.S., M.R.I.A., Director of the Armagh Observatory. Armagh.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. §Robinson, William. 40 Smithdown-road, Liverpool.
1870. *Robson, E. R. 17 Falkner-square, Liverpool.
1863. **Robson, James.*
*Robson, Rev. John, M.A., D.D 2 Queen's-crescent, Glasgow.
1855. ‡Robson, Neil, C.E. 127 St. Vincent-street, Glasgow.
1845. ‡*Rocow, Tattersall Thomas.*
1851. ‡Rodwell, William. Woodlands, Holbrook, Ipswich.
Roe, Henry, M.R.I.A. 2 Fitzwilliam-square East, Dublin.
1866. ‡Roe, Thomas. Grove Villas, Sitchurch.
1846. ‡Roe, William Henry. Portland-terrace, Southampton.
1861. §Rofe, John, F.G.S. 7 Queen-street, Lancaster.
1869. *Rogers, Nathaniel, M.D. 34 Paul-street, Exeter.
1860. ‡Rogers, James E. Thorold, Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S. Rosemill, by Dundee.
1870. §Rogers, T. L., M.D. Rainhill, Liverpool.
1859. ‡Rolleston, George, M.A., M.D., F.R.S., F.L.S., Professor of Anatomy and Physiology in the University of Oxford. The Park, Oxford.
1866. ‡Rolph, George Frederick. War Office, Horse Guards, London, S.W.
1863. ‡Romilly, Edward. 14 Hyde Park-terrace, London, W.
1845. ‡Ronalds, Sir Francis, F.R.S. 9 St. Mary's-villas, Battle, Sussex.
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1865. ‡Roper, R. S., F.G.S. Cwmbrae Iron Works, Newport, Monmouthshire.
1861. *Roscoe, Henry Enfield, B.A., Ph.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1861. ‡Rose, C. B., F.G.S. 25 King-street, Great Yarmouth, Norfolk.
1863. ‡Roseby, John. Haverholme House, Brigg, Lincolnshire.
1857. ‡Ross, David, LL.D. Drumbrain Cottage, Newbliss, Ireland.

Year of Election.

1859. **Ross, Rev. James Coulman. Dorchester Manor House, Wallingford.*
1861. *Ross, Thomas. 7 Wigmore-street, Cavendish-square, London, W.
1842. Ross, William. Pendleton, Manchester.
1869. *Rosse, The Right Hon. The Earl of, D.C.L., F.R.S., F.R.A.S. Birr Castle, Parsonstown, Ireland.
1855. ‡Roth, Dr. Matthias. 16A Old Cavendish-street, London, W.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1849. §Round, Daniel G. Hange Colliery, near Tipton, Staffordshire.
1847. ‡Rouse, William. 16 Canterbury Villas, Maida Vale, London, W.
1861. ‡Routh, Edward J., M.A. St. Peter's College, Cambridge.
1861. ‡Rowan, David. St. Vincent Crescent, Glasgow.
1855. ‡Rowand, Alexander. Linthouse, near Glasgow.
1865. §Rowe, Rev. John. Beaufort-villas, Edgbaston, Birmingham.
1855. *Rowney, Thomas H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway.
*Rowntree, Joseph. Leeds.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.
1859. ‡*Ruland, C. H.*
1869. §Rudler, F. W., F.G.S. 6 Pond-street, Hampstead, London, N.W.
1861. *Rumney, Robert, F.C.S. Springfield, Whalley Range, Manchester.
1856. ‡Rumsay, Henry Wildbore. Gloucester Lodge, Cheltenham.
1847. ‡Ruskin, John, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Denmark-hill, London, S.E.
1857. ‡Russell, Rev. C. W., D.D. Maynooth College.
1855. ‡Russell, James, jun. Falkirk.
1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.
1859. ‡Russell, John, the Right Hon. Earl, K.G., F.R.S., F.R.G.S. 37 Chesham-place, Belgrave-square, London, S.W.
Russell, John. 15 Middle Gardiner's-street, Dublin.
Russell, John Scott, M.A., F.R.S. L. & E. Sydenham; and 5 Westminster Chambers, London, S.W.
1852. *Russell, Norman Scott. 5 Westminster Chambers, London, S.W.
1863. ‡Russell, Robert. Gosforth Colliery, Newcastle-on-Tyne.
1852. *Russell, William J., Ph.D., Professor of Chemistry, St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London.
1862. §Russell, W. H. L., A.B., F.R.S. 5 The Grove, Highgate, London, N.
1865. ‡Rust, Rev. James, M.A. Manse of Slains, Ellon, N. B.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1852. ‡*Ryan, John, M.D.*
*Ryland, Arthur. The Linthurst, Broomsgrove, near Birmingham.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1853. ‡Rylands, Joseph. 9 Charlotte-street, Hull.
1861. *Rylands, Thomas Glazebrook, F.L.S., F.G.S. Heath House, Warrington.

*Sabine, General Sir Edward, K.C.B., R.A., LL.D., D.C.L., President of the Royal Society, F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, S.W.
1865. ‡Sabine, Robert. 3 Delahay-street, London, S.W.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
1848. ‡St. Davids, The Right Rev. Connop Thirlwall, D.D., F.G.S., Lord Bishop of. Abergwili, Carmarthen.
Salkeld, Joseph. Penrith, Cumberland.

Year of Election.

1857. ‡Salmon, Rev. George, D.D., D.C.L., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1864. ‡*Salmon, Henry C., F.G.S., F.C.S.*
1858. *Salt, Sir Titus, Bart. Methley Park, near Leeds.
1842. Sambrooke, T. G. 32 Eaton-place, London, S.W.
1861. *Samson, Henry. Messrs. Samson and Leppoc, 6 St. Peter's-square, Manchester.
1867. ‡Samuelson, Edward. Roby, near Liverpool.
1870. §Samuelson, James. St. Domingo-grove, Everton, Liverpool.
1861. *Sandeman, Archibald, M.A. Tulloch, Perth.
1857. ‡Sanders, Gilbert. The Hill, Monkstown, Co. Dublin.
*Sanders, William, F.R.S., F.G.S. Hanbury Lodge, The Avenue, Clifton, Bristol.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1854. ‡Sandon, Right Hon. Lord, M.P. 39 Gloucester-square, London, W.
1864. ‡Sanford, William A. Nynehead Court, Wellington, Somersetshire.
1865. ‡Sargant, W. L. Edmund-street, Birmingham.
Satterfield, Joshua. Alderley Edge.
1861. ‡Saul, Charles J. Smedley-lane, Cheetham-hill, Manchester.
1868. ‡Saunders, A., C.E. King's Lynn.
1846. ‡Saunders, Trelawney W. India Office, London, S.W.
1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1860. *Saunders, William. 3 Gladstone-terrace, Brighton.
1863. ‡Savory, Valentine. Cleckheaton, near Leeds.
1868. §Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.
1857. ‡Scallan, James Joseph. 77 Harcourt-street, Dublin.
1850. ‡Scarth, Pillans. 28 Barnard-street, Leith.
1868. §Schacht, G. F. 7 Regent's-place, Clifton, Bristol.
**Schemman, J. C. Hamburg.*
*Schlick, Count Benj. Quai Voltaire, Paris.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1842. Schofield, W. F. Madehurst Vicarage, Arundel.
*Scholes, T. Seddon. Irlam Lodge, Warwick-place, Leamington.
1847. *Scholey, William Stephenson, M.A. Freemantle Lodge, Bath-road, Reading.
Schunck, Edward, F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.
1861. *Schwabe, Edmund Salis. Rhodes House, near Manchester.
1867. ‡*Schwendler, Louis.*
1847. ‡Sclater, Philip Lutley, M.A, Ph.D., F.R.S., F.L.S., Sec. Zool. Soc. 11 Hanover-square, London, W.
1849. ‡Scoffern, John, M.B. Barnard's Inn, London; and Ilford, Essex.
1867. ‡Scott, Alexander. Clydesdale Bank, Dundee.
1865. §Scott, Major-General, Royal Bengal Artillery. Treledan Hall, Welshpool, Montgomeryshire.
1859. ‡Scott, Captain Fitzmaurice. Forfar Artillery.
1855. ‡Scott, Montague D., B.A. Hove, Sussex.
1857. §Scott, Robert H., M.A., F.R.S., F.G.S., Director of the Meteorological Office, 116 Victoria-street, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 14 Victoria-crescent, Dowanhill, Glasgow.
1864. ‡*Scott, Wentworth Lascelles.*
1858. ‡Scott, William. Holbeck, near Leeds.
1869. §Scott, William Bower. Chudleigh, Devon.
1864. ‡Scott, William Robson, Ph.D. St. Leonards, Exeter.
1869. §Searle, Francis Furlong. 5 Cathedral Yard, Exeter.
1859. ‡Seaton, John Love. Hull.

Year of Election.

1870. §Seaton, Joseph, M.D. Halliford House, Sandbury.
*Sedgwick, Rev. Adam, M.A., LL.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., F.R.G.S., Woodwardian Professor of Geology in the University of Cambridge, and Canon of Norwich. Trinity College, Cambridge.
1853. ‡Sedgwick, Rev. James. Scalby Vicarage, Scarborough.
1861. *Seeley, Harry Govier, F.G.S. St. John's College, Cambridge.
1855. ‡Seligman, H. L. 135 Buchanan-street, Glasgow.
*Selwyn, Rev. Canon William, M.A., D.D., F.R.S., Margaret Professor of Divinity in the University of Cambridge. Vine Cottage, Cambridge.
1858. *Senior, George, F.S.S. Rose Hill, Dodsworth, near Barnsley.
1870. *Sephton, Rev. J. Liverpool Institute, Mount-street, Liverpool.
1868. ‡Sewell, Philip E. Catton, Norwich.
Seymour, George Hicks. Stonegate, York.
1861. *Seymour, Henry D. Athenæum Club, Pall Mall, London, S.W.
Seymour, John. 21 Bootham, York.
1853. ‡Shackles, G. L. 6 Albion-street, Hull.
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, S.W.
1867. §Shanks, James. Den Iron Works, Arbroath, N. B.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. ‡Sharp, Samuel, F.G.S., F.S.A. Dallington Hall, near Northampton.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
Sharpey, William, M.D., LL.D., Sec. R.S., F.R.S.E., Professor of Anatomy and Physiology in University College. Lawnbank, Hampstead, London, N.W.
1869. *Shapter, Lewis. The Barnfield, Exeter.
1858. *Shaw, Bentley. Woodfield House, Huddersfield.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. §Shaw, Duncan. Cordova, Spain.
1858. ‡*Shaw, Edward W.*
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. §Shaw, John. 24 Great George-place, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1861. *Shaw, John. City-road, Hulme, Manchester.
1858. ‡Shaw, John Hope. Headingley, Leeds.
1853. ‡Shaw, Norton, M.D. St. Croix, West Indies.
Shepard, John. Nelson-square, Bradford, Yorkshire.
1870. §Shephard, Joseph. 29 Everton-crescent, Liverpool.
1863. ‡Shepherd, A. B. New University Club, St. James'-street, London, S.W.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1869. *Shepperd, Alfred Bayard. Torquay.
1869. ‡Sherard, Rev. S. H. Newton Abbot, Devon.
1851. ‡Shewell, John T. Rushmere, Ipswich.
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. §Shinn, William C. (ASSISTANT GENERAL TREASURER). Her Majesty's Printing Office, near Fetter-lane, London, E.C.
1864. ‡*Showers, Lieut.-Colonel Charles L. Cox's Hotel, Jermyn-street, London, S.W.*
1870. §Shoolbred, James N. York-buildings, Dale-street, Liverpool.
1842. Shuttleworth, John. Wilton Polygon, Cheetham-hill, Manchester.
1866. ‡Sibson, Francis, M.D., F.R.S. 59 Brook-street, Grosvenor-square, London, W.

Year of Election.

1861. *Sidebotham, Joseph. 19 George-street, Manchester.
1861. *Sidebottom, James. Mersey Bank, Heaton Mersey, Manchester.
1857. ‡Sidney, Frederick John. 19 Herbert-street, Dublin.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1856. §Siemens, C. William, D.C.L., F.R.S. 3 Great George-street, London, S.W.
*Sillar, Zechariah, M.D. Bath House, Laurie Park, Sydenham, London, S.E.
1859. ‡Sim, John. Hardgate, Aberdeen.
1855. ‡Sim, William. Furnace, near Inverary.
1865. §Simkiss, T. M. Wolverhampton.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1852. ‡Simms, William. Albion-place, Belfast.
1847. ‡Simon, John. King's College, London, W.C.
1866. ‡Simons, George. The Park, Nottingham.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Marykirk, Kincardineshire.
1863. §Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡Simpson, Maxwell, M.D., F.R.S., F.C.S. 1 Brougham-place, Dublin.
*Simpson, Rev. Samuel. Greaves House, near Lancaster.
Simpson, Thomas. Blake-street, York.
Simpson, William. Bradmore House, Hammersmith, London, W.
1859. ‡Sinclair, Alexander. 133 George-street, Edinburgh.
1850. ‡Sinclair, Rev. William. Leeds.
1870. *Sinclair, W. P. 32 Devonshire-roads, Prince's-park, Liverpool.
1864. *Sircar, Baboo Mohendro Lall, M.D. 1344 San Kany, Tollah-street, Calcutta, per Messrs. Harrenden & Co., 3 Chaple-place, Poultry, London, E.C.
1865. §Sissons, William. 92 Park-street, Hull.
1850. ‡Skae, David, M.D. Royal Asylum, Edinburgh.
1859. ‡*Skinner, James.*
1870. §Slater, W. B. 28 Hamilton-square, Birkenhead.
1842. *Slater, William. 75 Princes-street, Manchester.
1853. §Sleddon, Francis. 2 Kingston-terrace, Hull.
1849. §Sloper, George Edgar, jun. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860. §Sloper, S. Elgar. Winterton, near Southampton.
1867. ‡Small, David. Gray House, Dundee.
1867. ‡Small, William. Dundee.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1867. ‡Smeiton, John G. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, Thomas A. 55 Cowgate, Dundee.
1868. §Smith, Augustus. Northwood House, Church-road, Upper Norwood, Surrey.
1857. ‡Smith, Aquila, M.D., M.R.I.A. 121 Lower Bagot-street, Dublin.
Smith, Archibald, M.A., LL.D., F.R.S. L. & E. River-bank, Putney; and 3 Stone-buildings, Lincoln's Inn, London, W.C.
Smith, Rev. B., F.S.A.
1861. *Smith, Charles Edward, F.R.A.S. St. Margaret's, Beulah Hill, Upper Norwood, London, S.E.
1865. §Smith, David, F.R.A.S. 4 Cherry-street, Birmingham.
1853. ‡Smith, Edmund. Ferriby, near Hull.
1859. ‡Smith, Edward, M.D., LL.B., F.R.S. 140 Harley-street, London, W.
1865. ‡Smith, Frederick. The Priory, Dudley.
1866. *Smith, F. C., M.P. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1855. ‡Smith, George Cruickshank. 19 St. Vincent-place, Glasgow.

Year of
Election.

*Smith, Rev. George Sidney, D.D., M.R.I.A., Professor of Biblical Greek in the University of Dublin. Riverland, Omagh, Ireland.
1859. ‡*Smith, Henry A. 5 East Craibstone-street, Aberdeen.*
*Smith, Henry John Stephen, M.A., F.R.S., F.C.S., Savilian Professor of Geometry in the University of Oxford. 64 St. Giles's, Oxford.
1860. *Smith, Heywood, M.A., M.B. 42 Park-street, Grosvenor-square, London, W.
1865. ‡Smith, Isaac. 26 Lancaster-street, Birmingham.
1870. §Smith, James. 146 Bedford-street South, Liverpool.
1842. *Smith, James. Berkeley House, Seaforth, near Liverpool.
1855. ‡Smith, James. St. Vincent-street, Glasgow.
1850. ‡*Smith, John, M.D.*
1853. ‡Smith, John. York City and County Bank, Malton, Yorkshire.
1858. *Smith, John Metcalf. Old Bank, Leeds.
1867. §Smith, John P., C.E. 67 Renfield-street, Glasgow.
Smith, John Peter George. Spring Bank, Anfield, Liverpool.
1864. §Smith, John S. Sydney Lodge, Wimbledon, Surrey.
1852. *Smith, Rev. Joseph Denham. Bellevue, Blackrock, Co. Dublin.
1861. ‡Smith, Professor J., M.D. University of Sydney, Australia.
*Smith, Philip, B.A. 4 Cambridge-terrace, Junction-road, London, N.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1847. §Smith, Robert Angus, Ph.D., F.R.S., F.C.S. 22 Devonshire-street, Manchester.
*Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870. §Smith, Samuel. Bank of Liverpool, Liverpool.
1866. §Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1867. ‡Smith, Thomas (Sheriff). Dundee.
1867. §Smith, Thomas. Pole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1857. §Smith, William, C.E., F.G.S., F.R.G.S. 19 Salisbury-street, Adelphi, London, W.C.
1850. *Smyth, Charles Piazzi, F.R.S. L. & E., F.R.A.S., Astronomer Royal for Scotland, Professor of Practical Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1870. §Smyth, Colonel H. A., R.A.
1870. §Smyth, H. L. Crabwall Hall, Cheshire.
1857. *Smyth, John, jun., M.A., M.I.C.E.I., F.M.S. Milltown, Banbridge, Ireland.
1868. ‡Smyth, Rev. J. D. Hurst. 13 Upper St. Giles's-street, Norwich.
1864. ‡Smyth, Warington W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 13 Victoria-street, London, S.W.
1854. ‡Smythe, Colonel W. J., R.A., F.R.S. Bombay.
Soden, John. Athenæum Club, Pall Mall, London, S.W.
1853. ‡Sollitt, J. D., Head Master of the Grammar School, Hull.
*Solly, Edward, F.R.S., F.L.S., F.G.S., F.S.A. Sandecotes, near Poole
*Sopwith, Thomas, M.A., F.R.S., F.G.S., F.R.G.S. 103 Victoria-street, Westminster, S.W.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *Sorby, H. Clifton, F.R.S., F.G.S. Broomfield, Sheffield.
1861. ‡Sorensen, Le Chevalier B. Norway.

Year of Election.

1865. *Southall, John Tertius. Leominster.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1863. *Spark, H. King. Greenbank, Darlington.
1859. ‡Spence, Rev. James, D.D. 6 Clapton-square, London, N.E.
*Spence, Joseph. 60 Holgate Hill, York.
1869. *Spence, J. Berger. Erlington House, Manchester.
1854. §Spence, Peter. Pendleton Alum Works, Newton Heath; and Smedley Hall, near Manchester.
1861. §Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. 27 Brown-street, Manchester.
1863. *Spencer, Thomas. The Grove Ruban, near Blaydon-on-Tyne.
1855. ‡Spens, William. 78 St. Vincent-street, Glasgow.
1864. *Spicer, Henry, jun., F.G.S. 22 Highbury-crescent; and 19 New Bridge-street, Blackfriars, London, E.C.
Spicer, Thomas Trevetham, M.A., LL.D.
1864. §Spicer, William R. 19 New Bridge-street, Blackfriars, London, E.C.
1847. *Spiers, Richard James, F.S.A. 14 St. Giles's-street, Oxford.
1868. *Spiller, Edmund Pim. 3 Furnival's Inn, London, E.C.
1864. *Spiller, John, F.C.S. 35 Grosvenor-road, Highbury New Park, London, N.
1846. *Spottiswoode, William, M.A., F.R.S., F.R.A.S., F.R.G.S. (General Treasurer). 50 Grosvenor-place, London, S.W.
1864. *Spottiswoode, W. Hugh. 50 Grosvenor-place, London, S.W.
1854. *Sprague, Thomas Bond. 4 Lansdowne-place, Blackheath, London, S.E.
1853. ‡Spratt, Joseph James. West Parade, Hull.
Square, Joseph Elliot, F.G.S. 24 Portland-place, Plymouth.
*Squire, Lovell. The Observatory, Falmouth.
1859. ‡Stables, William Alexander. Cawdor Castle, Nairn, N.B.
1857. ‡*Stack, Rev. Thomas. Dublin.*
1858. *Stainton, Henry T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, Kent.
1851. *Stainton, James Joseph, F.L.S., F.C.S. Meadowcroft, Lewisham, London, S.E.
1858. ‡Stanfield, Alfred W. Wakefield.
1865. §Stanford, Edward C. C. Edinbarnet, Dumbartonshire.
Stanley, The Very Rev. Arthur Penrhyn, D.D., F.R.S., Dean of Westminster. The Deanery, Westminster, London, S.W.
Stapleton, H. M. 1 Mountjoy-place, Dublin.
1866. §Starey, Thomas R. Daybrook House, Nottingham.
1850. ‡Stark, James, M.D., F.R.S.E. 21 Rutland-street, Edinburgh.
1863. ‡Stark, Richard M. Hull.
Staveley, T. K. Ripon, Yorkshire.
1857. ‡Steel, William Edward, M.D. 15 Hatch-street, Dublin.
1863. §Steele, Rev. Dr. 2 Bathwick-terrace, Bath.
1861. ‡Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
Stenhouse, John, LL.D., F.R.S., F.C.S. 17 Rodney-street, Pentonville, London, N.
1870. §Stearn, C. H. 3 Elden-terrace, Rock Ferry, Liverpool.
1861. *Stern, S. J. Rusholme House, Manchester.
1863. §Sterriker, John. Driffield.
1870. *Stevens, Miss Anna Maria. Wiley, near Salisbury.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1863. ‡Stevenson, Archibald. South Shields.
1850. ‡Stevenson, David. 8 Forth-street, Edinburgh.

Year of Election.

Stevenson, Rev. Edward, M.A.
1868. ‡Stevenson, Henry, F.L.S. 10 Unthank-road, Norwich.
1863. *Stevenson, James C. Westoe, South Shields.
1855. Stewart, Balfour, M.A., LL.D., F.R.S., Professor of Natural Philosophy in Owen's College, Manchester, Superintendent of the Kew Observatory of the British Association. Owen's College, Manchester.
1864. ‡Stewart, Charles, F.L.S. 19 Princess Square, Plymouth.
1856. *Stewart, Henry Hutchinson, M.D., M.R.I.A. 71 Eccles-street, Dublin.
1869. §Stewart, J. L. East India United Service Club, 14 St. James's-square, London, S.W.
Stewart, Robert. Glasgow.
1847. ‡Stewart, Robert, M.D. The Asylum, Belfast.
1867. ‡Stirling, Dr. D. Perth.
1868. §Stirling, Edward. 34 Queen's-gardens, Hyde Park, London, W.
1867. *Stirrup, Mark. 2 Harwood-place, Old Trafford, Manchester.
1865. *Stock, Joseph S. Showell Green, Spark Hill, near Birmingham.
1862. ‡Stockil, William. 5 Church Meadows, Sydenham, London, S.E.
Stoddart, George. 11 Russell-square, London, W.C.
1864. §Stoddart, William Walter, F.G.S., F.C.S. 7 King-square, Bristol.
1854. ‡Stoess, Le Chevalier, Ch. de W. (Bavarian Consul). Liverpool.
*Stokes, George Gabriel, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambrdge. Lensfield Cottage, Lensfield-road, Cambridge.
1845. ‡Stokes, Rev. William H., M.A., F.G.S. Cambridge.
1862. ‡Stone, Edward James, M.A., F.R.S., F.R.A.S., Astronomer Royal at the Cape of Good Hope. Cape Town.
1859. ‡Stone, Dr. William H. 13 Vigo-street, London, W.
1857. ‡Stoney, Bindon B., M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1861. *Stoney, George Johnstone, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. 40 Wellington-road, Dublin.
1854. ‡Store, George. Prospect House, Fairfield, Liverpool.
1867. §Storrar, John, M.D. Heathview, Hampstead, London, N.W.
1859. §Story, James. 17 Bryanston-square, London, W.
1859. ‡*Strachan, Patrick.*
1863. ‡Strachan, T. Y. Lovaine-crescent, Newcastle-on-Tyne.
1863. ‡Straker, John. Wellington House, Durham.
1868. §Strange, Lieut.-Colonel A., F.R.S., F.R.A.S., F.R.G.S. India Stores, Belvedere-road, Lambeth, London, S.E.
*Strickland, Charles. Loughglyn House, Castherea, Ireland.
Strickland, William. French-park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1867. §Stronner, D. 14 Princess-street, Dundee.
1866. *Strutt, The Hon. Arthur, F.G.S. Duffield, near Derby.
1868. *Strutt, The Hon. John W. Terling-place, Witham, Essex.
1861. ‡*Stuart, W. D. Philadelphia.*
1859. ‡*Stuart, William Henry.*
1866. ‡*Stubbins, Henry.*
1864. ‡Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
1857. ‡Sullivan, William K., Ph.D., M.R.I.A. Museum of Irish Industry; and 53 Upper Leeson-road, Dublin.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *Sutherland, George Granville William, Duke of, K.G., F.R.G.S. Stafford House, London, S.W.
1855. ‡Sutton, Edwin. 44 Winchester-street, Pimlico, London, S.W.
1863. §Sutton, Francis, F.C.S. Bank Plain, Norwich.

Year of Election.

1861. *Swan, Patrick Don S. Kirkaldy, N.B.
1862. *Swan, William, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews. 2 Hope-street, St. Andrews, N. B.
1862. *Swann, Rev. S. Kirke. Gedling, near Nottingham.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburn, Sir John. Capheaton, Newcastle-on-Tyne.
1863. §Swindell, J. S. E. Summerhill, Kingswinford, Dudley.
1863. ‡Swinhoe, Robert, F.R.G.S. Oriental Club, London, W.
1870. §Swinhoe, Robert. 33 Oakley-square, London, S.W.
1859. ‡*Sykes, Alfred. Leeds.*
1847. ‡Sykes, H. P. 47 Albion-street, Hyde Park, London, W.
1862. ‡Sykes, Thomas. Cleckheaton, near Leeds.
*Sykes, Colonel William Henry, M.P., F.R.S., Hon. M.R.I.A., F.G.S., F.R.G.S. 47 Albion-street, Hyde Park, London, W.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London. W.
Sylvester, James Joseph, M.A., LL.D., F.R.S., 60 Maddox-street, W., and Athenæum Club, London, S.W.
1870. §Symes, R. G. Dublin.
1856. *Symonds, Frederick, F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡Symonds, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §Symons, G. J., F.M.S. 62 Camden-square, London, N.W.
1855. *Symons, William, F.C.S. 26 Joy-street, Barnstaple.
Synge, Rev. Alexander. St. Peter's, Ipswich.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
Synge, John Hatch. Glanmore, Ashford, Co. Wicklow.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N. B.
1867. ‡Tait, P. M., F.R.G.S. 26 Adelaide Road, N.; and Oriental Club, Hanover-square, London, W.
§Talbot, William Hawkshead. Hartwood Hall, Chorley, Lancashire.
Talbot, William Henry Fox, M.A., LL.D., F.R.S., F.L.S. Lacock Abbey, near Chippenham.
1867. *Tanner, Thomas Hawkes, M.D., F.L.S. 9 Henrietta-street, Cavendish-square, London, W.
Taprell, William. 7 Westbourne-crescent, Hyde Park, London, W.
1866. ‡Tarbottom, Marrott Ogle, M.I.C.E., F.G.S. Newstead-grove, Nottingham.
1861. *Tarratt, Henry W. Bushbury Lodge, Leamington.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1864. ‡*Tasker, Rev. J. C. W.*
1857. *Tate, Alexander. 2 Queen's Elms, Belfast.
1863. Tate, John. Alnmouth, near Alnwick, Northumberland.
1870. §Tate, Norman A. 7 Nivell Chambers, Fazackerley-street, Liverpool.
1865. ‡Tate, Thomas. White Horse Hill, Chislehurst, Kent.
1858. *Tatham, George. Springfield Mount, Leeds.
1864. *Tawney, Edward B., F.G.S. Ashbury Dale, Torquay.
1867. ‡Taylor, Rev. Andrew. Dundee.
Taylor, Frederick. Messrs. Taylor, Potter & Co., Liverpool.
*Taylor, James. Culverlands, near Reading.
*Taylor, John, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1861. *Taylor, John, jun. Sandycroft, Chester.
1863. ‡Taylor, John. Earsdon, Newcastle-on-Tyne.
1863. ‡Taylor, John. Lovaine-place, Newcastle-on-Tyne.
1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.

Year of Election.

**Taylor, Vice-Admiral J. N., C.B.*
Taylor, Captain P. Meadows, in the Service of His Highness the Nizam. Harold Cross, Dublin.
*Taylor, Richard, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1870. §Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
Taylor, Rev. William, F.R.S., F.R.A.S. Thornloe, Worcester.
*Taylor, William Edward. Millfield House, Enfield, near Accrington.
1858. ‡Teale, Joseph. Leeds.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
Teather, John. Alstonley, Cumberland.
1869. ‡Teesdale, C. S. M. Pennsylvannia, Exeter.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
*Tennant, James, F.G.S., F.R.G.S., Professor of Mineralogy in King's College. 149 Strand, London, W.C.
1857. ‡Tennison, Edward King. Kildare-street Club House, Dublin.
1849. ‡Teschemacher, E. F. Highbury-park North, London, N.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1859. ‡Thain, Rev. Alexander. New Machar, Aberdeen.
1856. ‡*Thodey, Rev. S. Rodborough, Gloucestershire.*
Thom, John. Messrs. McNaughton & Co., Moseley-street, Manchester.
1870. §Thom, Robert Wilson. Lark Hill, Chorley, Lancashire.
Thomas, George. Brislington, Bristol.
1848. **Thomas, George John, M.A.*
1869. ‡Thomas, H. D. Fore-street, Exeter.
1869. §Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
*Thompson, Corden, M.D. Norfolk-street, Sheffield.
1863. ‡Thompson, Rev. Francis. St. Giles's, Durham.
1858. *Thompson, Frederick. South Parade, Wakefield.
1859. §Thompson, George, jun. Pidsmedden, Aberdeen.
1870. §Thomson, Sir Henry. 35 Wimpole-street, London. W.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
Thompson, Henry Stafford. Fairfield, near York.
1861. *Thompson, Joseph. Woodlands, Wilmslow, near Manchester.
1864. §Thompson, Rev. Joseph Hesselgrave, B.A. Cradley, near Brierley-hill.
Thompson, Leonard. Sheriff-Hutton Park, Yorkshire.
1853. ‡Thompson, Thomas (Austrian Consul). Hull.
Thompson, Thomas (Town Clerk). Hull.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen Yard-road, Dundee.
1855. ‡Thomson, Allen, M.D., Professor of Anatomy in the University of Glasgow.
1867. ‡Thomson, Francis Hay, M.D. Glasgow.
1852. ‡Thomson, Gordon A. Bedeque House, Belfast.
Thomson, Guy. Oxford.
1855. ‡Thomson, James. 82 West Nile-street, Glasgow.
1850. *Thomson, Professor James, M.A., C.E. 17 University-square, Belfast.
1868. §Thomson, James, F.G.S. 276 Eglington-street, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1863. ‡Thomson, M. 8 Meadow-place, Edinburgh.
1865. ‡Thomson, R. W., C.E., F.R.S.E. 3 Moray-place, Edinburgh.
1850. ‡Thomson, Thomas, M.D., F.R.S., F.L.S. (GENERAL SECRETARY). 16 Horbury-crescent, Notting-hill, London, W.
1847. *Thomson, Sir William, M.A., LL.D., D.C.L., F.R.S. L. & E., PRESIDENT ELECT, Professor of Natural Philosophy in the University of Glasgow. The College, Glasgow.
1870. §Thomson, W. C., M.D. 7 Domingo Vale, Everton, Liverpool.

Year of Election.

1850. ‡Thomson, Wyville T. C., LL.D., F.R.S., F.G.S., Regius Professor of Natural History in the University of Edinburgh.
1852. ‡Thorburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1865. *Thornley, S. Gilbertstone House, Bickenhill, near Birmingham.
1866. ‡Thornton, James. Edwalton, Nottingham.
*Thornton, Samuel. Oakfield, Moseley, near Birmingham.
1867. ‡Thornton, Thomas. Dundee.
1845. ‡Thorp, Dr. Disney. Suffolk Laun, Cheltenham.
*Thorp, The Venerable Thomas, B.D., F.G.S., Archdeacon of Bristol. Kemerton, near Tewkesbury.
1864. *Thorp, William, jun., F.C.S. 39 Sandringham-road, West Hackney, London, N.E.
1868. ‡Thuillier, Colonel. 27 Lower Seymour-street, Portman-square, London, W.
Thurnam, John, M.D. Devizes.
1856. ‡Tibbs, Somerset. 58 Regent-street, Cheltenham.
1870. §Tichborne, Charles R. S., F.C.S. Apothecaries' Hall of Ireland, Dublin.
1865. §Timmins, Samuel. Elvetham-road, Edgbaston, Birmingham.
Tinker, Ebenezer. Mealhill, near Huddersfield.
*Tinné, John A., F.R.G.S. Briarly, Aigburth, Liverpool.
Tite, Sir William, M.P., F.R.S., F.G.S., F.S.A. 42 Lowndes-square, London, S.W.
Tobin, Rev. John. Liscard, Cheshire.
1859. ‡Todd, Thomas. Mary Culter House, Aberdeen.
1861. *Todhunter, Isaac, M.A., F.R.S. Principal Mathematical Lecturer of St. John's College, Cambridge. Bourne House, Cambridge.
Todhunter, J. 3 College Green, Dublin.
1857. ‡Tombe, Rev. H. J. Ballyfree, Ashford, Co. Wicklow.
1856. ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.
1866. §Tomlin, J. R. Stoke Field, Newark.
1864. *Tomlinson, Charles, F.R.S., F.C.S. 3 Ridgmount-terrace, Highgate, London, N.
1863. ‡Tone, John F. Jesmond Villas, Newcastle-on-Tyne.
1865. §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. §Tonks, William Henry. 4 Carpenter-road, Edgbaston, Birmingham.
1861. *Topham, John, A.I.C.E. High Elms, Hackney, London, N.E.
1863. ‡Torr, F. S. 38 Bedford-row, London, W.C.
1863. ‡Torrens, R. R., M.P. 2 Gloucester-place, Hyde Park, London, W.
1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neots, Huntingdonshire.
1860. ‡Townsend, John. 11 Burlington-street, Bath.
1857. ‡Townsend, Rev. Richard, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1854. ‡Towson, John Thomas, F.R.G.S. 47 Upper Parliament-street, Liverpool; and Local Marine Board, Liverpool.
1859. ‡Trail, Rev. Robert, M.A. Boyndie, Banff.
1859. ‡Trail, Samuel, D.D., LL.D. The Manse, Hayay, Orkney.
1870. §Traill, William A. 14 Hume-street, Dublin.
1868. §Traquair, Ramsay H., M.D., Professor of Zoology, Royal College of Science, Dublin.
1865. ‡Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.
1859. ‡*Trefusis, The Hon. C.*
Tregelles, Nathaniel. Neath Abbey, Glamorganshire.
1868. §Trehane, John. Exe View Lawn, Exeter.
1869. ‡Trehane, John, jun. Bedford-circus, Exeter.
1870. §Trench, Dr. Municipal Offices, Duke-street, Liverpool.

Year of Election.

Trench, F. A. Newlands House, Clondalkin, Ireland.
*Trevelyan, Arthur. Tyneholme Tranent, Haddingdonshire.
Trevelyan, Sir Walter Calverley, Bart., M.A., F.R.S.E., F.G.S., F.S.A., F.R.G.S. Athenæum Club, London, S.W.; Wallington, Northumberland; and Nettlecombe, Somerset.
1869. §Tristram, Rev. Henry Baker, M.A., LL.D., F.R.S., F.L.S. Greatham Hospital, near Stockton-on-Tees.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1864. ‡Truell, Robert. Ballyhenry, Ashford, Co. Wicklow.
1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. 10 Balwin-street, Bristol.
Tuckett, Frederick. 4 Mortimer-street, Cavendish-square, London, W.
Tuke, J. H. Bank, Hitchen.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.
1865. §Turbervile, H. Pilton, Barnstaple.
1854. ‡Turnbull, James, M.D. 86 Rodney-street, Liverpool.
1855. §Turnbull, John. 37 West George-street, Glasgow.
1856. ‡Turnbull, Rev. J. C. 8 Bays-hill Villas, Cheltenham.
*Turnbull, Rev. Thomas Smith, M.A., F.R.S., F.G.S., F.R.G.S. Blofield, Norfolk.
Turner, Thomas, M.D. 31 Curzon-street, May Fair, London, W.
1863. ‡Turner, William, M.B., F.R.S.E., Professor of Anatomy in the University of Edinbugh. The University, Edinburgh.
1842. Twamley, Charles, F.G.S. 11 Regent's Park-road, London, N.W.
1859. ‡Twining, H. R. Grove Lodge, Clapham, London, S.W.
1847. ‡Twiss, Sir Travers, D.C.L., F.R.S., F.R.G.S., Regius Professor of Civil Law in the University of Oxford, and Chancellor of the Diocese of London. 19 Park-lane, London, W.
1846. ‡Tylor, Alfred, F.G.S. Warwick-lane, London, E.C.
1865. §Tylor, Edward Burnett. Lindon, Wellington, Somerset.
1858. *Tyndall, John, LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. Royal Institution, Albemarle-street, London, W.
1861. *Tysoe, John. Seedley-road, Pendleton, near Manchester.

Upton, Rev. James Samuel, M.A., F.G.S.
1855. ‡Ure, John. 114 Montrose-street, Glasgow.
1859. ‡Urquhart, Rev. Alexander. Tarbat, Ross-shire.
1859. ‡Urquhart, W. Pollard. Craigston Castle, N. B.; and Castlepollard, Ireland.
1866. §Urquhart, William W. Springfield House, Dundee.

1870. §Vale, H. H. 42 Prospect Vale, Fairfield, Liverpool.
1854. ‡*Vale, James Theodorick. Hamilton-square, Birkenhead.*
*Vallack, Rev. Benjamin W. S. St. Budeaux, near Plymouth.
*Vance, Rev. Robert. 24 Blackhall-street, Dublin.
1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1853. §Varley, Cornelius. 337 Kentish Town-road, London, N.W.
1854. ‡*Varley, Cromwell F. Fleetwood House, Beckenham, Kent.*
1868. §Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay Avenue, Stoke Newington, London, N.
1865. *Varley, S. Alfred. 66 Roman-road, Holloway, London, N.
1870. §Varley, Mrs. S. A. 66 Roman-road, Holloway-road, London, N.
1869. ‡Varwell, P. Alphington-street, Exeter.
1863. ‡Vauvert, de Mean A., Vice-Consul for France. Tynemouth.
1849. *Vaux, Frederick. Central Telegraph Office, Adelaide, South Australia.

Year of Election.

Verney, Sir Harry, Bart., M.P. Lower Claydon, Buckinghamshire.
1866. ‡Vernon, Rev. E. H. Harcourt. Cotgrave Rectory, near Nottingham.
Vernon, George John, Lord. 32 Curzon-street, London, W.; and Sudbury Hall, Derbyshire.
1854. *Vernon, George V., F.R.A.S. 1 Osborne-place, Old Trafford, Manchester.
1854. *Vernon, John. Gateacre, Liverpool.
1864. *Vicary, William, F.G.S. The Priory, Colleton-crescent, Exeter.
1854. *Vignoles, Charles B., C.E., F.R.S., M.R.I.A., F.R.A.S., V.P.I.C.E. 21 Duke-street, Westminster, S.W.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1856. ‡Vivian, Edward, B.A. Woodfield, Torquay.
*Vivian, H. Hussey, M.P., F.G.S. Park Wern, Swansea; and 7 Belgrave-square, London, S.W.
1856. §Voelcker, J. Ch. Augustus, Ph.D., F.R.S., F.C.S., Professor of Chemistry to the Royal Agricultural Society of England. 39 Argyll-road, Kensington, London, W.
‡Vose, Dr. James. Gambier-terrace, Liverpool.

1860. §Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1859. ‡Waddington, John. New Dock Works, Leeds.
1855. *Waldegrave, The Hon. Granville. 26 Portland-place, London, W.
1870. §Waley, Jacob. 20 Wimpole-street, London, W.
1869. *Walford, Cornelius. Little Park, Enfield.
1870. §Wake, Charles Staniland. 4 St. Martin's-place, Trafalgar-square, London, W.C.
1863. ‡*Walker, Alfred O.*
1849. §Walker, Charles V., F.R.S., F.R.A.S. Fernside Villa, Redhill, near Reigate.
Walker, Sir Edward S. Berry Hill, Mansfield.
Walker, Francis, F.L.S., F.G.S. Elm Hall, George-lane, Wanstead, London, N.
Walker, Frederick John. Alltyr Odyn, Llandyssil, Carmarthen.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1859. ‡Walker, James. 16 Norfolk-crescent, London, W.
1855. ‡Walker, John. 1 Exchange-court, Glasgow.
1842. *Walker, John. Thorncliffe, New Kenilworth-road, Leamington.
1855. ‡*Walker, John James, M.A. 2 Trinity College, Dublin.*
1866. *Walker, J. F. Sidney College, Cambridge.
1867. *Walker, Peter G. Dundee.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1869. *Walker, Thomas F. W., M.A., F.R.G.S. 6 Brock-street, Bath.
Walker, William. 47 Northumberland-street, Edinburgh.
1869. ‡Walkey, J. E. C. High-street, Exeter.
Wall, Rev. R. H., M.A. 6 Hume-street, Dublin.
1863. §Wallace, Alfred R., F.R.G.S. Holly House, Barking, Essex.
1859. ‡Wallace, William, Ph.D., F.C.S. Chemical Laboratory, 3 Bath-street, Glasgow.
1857. ‡Waller, Edward. Lisenderry, Aughnacloy, Ireland.
1862. ‡Wallich, George Charles, M.D., F.L.S. 11 Earls-terrace, Kensington, London, W.
Wallinger, Rev. William. Hastings.
Walmsley, Sir Joshua, Knt.
1862. ‡Walpole, The Right Hon. Spencer Horatio, M.A., D.C.L., M.P., F.R.S. Ealing, near London.
1857. ‡Walsh, Albert Jasper. 89 Harcourt-street, Dublin.
Walsh, John (Prussian Consul). 1 Sir John's Quay, Dublin.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.

Year of Election.

Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863. ‡Wanklyn, James Alfred, F.R.S.E., F.C.S. London Institution, Finsbury-circus, London, E.C.
1857. ‡Ward, John S. Prospect-hill, Lisburn, Ireland.
Ward, Rev. Richard, M.A. 12 Eaton-place, London, S.W.
1863. ‡Ward, Robert. Dean-street, Newcastle-on-Tyne.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
Wardell, William. Chester.
1867. ‡Warden, Alexander J. Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 55 Parliament-street, London, S.W.
1864. *Warner, Edward. 49 Grosvenor-place, London, S.W.
1856. ‡Warner, Thomas H. Lee. Tiberton Court, Hereford.
1869. §Warren, James L. Letterfrack, Galway.
1865. *Warren, Edward P., L.D.S. 13 Old-square, Birmingham.
Warwick, William Atkinson. Wyddrington House, Cheltenham.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
*Waterhouse, John, F.R.S., F.G.S., F.R.A.S. Wellhead, Halifax, Yorkshire.
1854. ‡Waterhouse Nicholas. 5 Rake-lane, Liverpool.
1870. §Waters, A. T. H., M.D. 29 Hope-street, Liverpool.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡Watson, Ebenezer. 16 Abercromby-place, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorn House, Cringleford, Norwich.
*Watson, Henry Hough, F.C.S. 227 The Folds, Bolton-le-Moors.
Watson, Hewett Cottrell. Thames Ditton, Surrey.
1855. ‡Watson, James, M.D. 152 St. Vincent-street, Glasgow.
1859. ‡Watson, John Forbes, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham Grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. §Watson, Thomas D. 18 A Basinghall-street, London, E.C.
1858. ‡Watson, William. Bilton House, Harrogate.
1869. ‡Watt, Robert B. E. Ashby-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1846. §Watts, John King, F.R.G.S. St. Ives, Huntingdonshire.
1870. §Watts, William. Corporation Waterworks, Swineshaw, Staleybridge.
1858. ‡Waud, Major E. Manston Hall, near Leeds.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1862. §Waugh, Major-General Sir Andrew Scott, R.E., F.R.S., F.R.A.S., F.R.G.S., late Surveyor-General of India, and Superintendent of the Great Trigonometrical Survey. 7 Petersham-terrace, Queen's Gate-gardens, London, W.
1859. ‡Waugh, Edwin. Sager-street, Manchester.
*Way, J. Thomas, F.C.S., 9 Russell-road, Kensington, London, S.W.
1869. ‡Way, Samuel James. Adelaide, South Australia.
*Webb, Rev. Thomas William, M.A., F.R.A.S. Hardwick Parsonage, Hay, South Wales.
1866. *Webb, William Frederick, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1856. ‡Webster, James. Hatherley Court, Cheltenham.
1859. ‡Webster, John. 42 King-street, Aberdeen.
1858. ‡Webster, John. Broomhall Park, and St. James's-row, Sheffield.
1862. ‡Webster, John Henry, M.D. Northampton.
1864. §Webster, John. Belvoir-terrace, Sneinton, Nottingham.

Year of Election.

Webster, Thomas, M.A., F.R.S. 2 Pump Court, Temple, London, E.C.
1845. ‡Wedgewood, Hensleigh. 17 Cumberland-terrace, Regent's Park, London, N.W.
1854. ‡Weightman, William Henry. Farn Lea, Seaforth, Liverpool.
1865. ‡Welch, Christopher, M.A. University Club, Pall Mall East, London, S.W.
1867. §Weldon, Walter. Park-villa, West Hill, Highgate, London, N.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Whitehaven, Cumberland.
1865. ‡Wesley, William Henry. 31 Clayland-road, Clapham, London, S.W.
1853. ‡West, Alfred. Holderness-road, Hull.
1870. §West, Captain E. W. Bombay.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1853. ‡West, Stephen. Hessle Grange, near Hull.
1851. *Western, Sir T. B., Bart. Felix Hall, Kelvedon, Essex.
1870. §Westgarth, William. 28 Cornhill, London, E.C.
1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.
Westhead, John. Manchester.
1842. *Westhead, Joshua Proctor Brown. Lea Castle, near Kidderminster, Scotland.
1857. *Westley, William. 24 Regent-street, London, S.W.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1860. §Weston, James Woods. Seedley House, Pendleton, Manchester.
1864. §Westropp, W. H. S., M.R.I.A. 2 Idrone-terrace, Blackrock, Dublin.
1860. ‡Westwood, John O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1853. ‡Wheatley, E. B. Cote Wall, Merfield, Yorkshire.
Wheatstone, Sir Charles, D.C.L., F.R.S., Hon. M.R.I.A., Professor of Experimental Philosophy in King's College, London. 19 Park-crescent, Regent's Park, London, N.W.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London.
1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.
1853. ‡Whitaker, Charles. Milton Hill, near Hull.
1859. *Whitaker, William, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1866. §White, Charles, F.R.G.S. Barnesfield House, near Dartford, Kent; and 10 Lime-street, London, E.C.
1864. §White, Edmund. Victoria Villa, Batheaston, Bath.
1837. ‡White, James, M.P., F.G.S. 14 Chichester-terrace, Kemp Town, Brighton.
White, John. 80 Wilson-street, Glasgow.
1859. ‡White, John Forbes. 16 Bon Accord-square, Aberdeen.
1865. ‡White, Joseph. Regent's-street, Nottingham.
1869. §White, Laban. St. Catherine's College, Cambridge.
1859. ‡White, Thomas Henry. Tandragee, Ireland.
1861. ‡Whitehead, James, M.D. 87 Mosley-street, Manchester.
1858. ‡Whitehead, J. H. Southsyde, Saddleworth.
1861. *Whitehead, John B. Ashday Lea, Rawtenstall, Manchester.
1861. *Whitehead, Peter Ormerod. Belmont, Rawtenstall, Manchester.
1855. *Whitehouse, Wildeman W. O. Roslyn House Hill, Pilgrim-lane, Hampstead, London, N.
Whitehouse, William. 10 Queen-street, Rhyl.
*Whiteside, James, M.A., LL.D., D.C.L., Lord Chief Justice of Ireland. 2 Mountjoy-square, Dublin.

Year of Election.

1866. §Whitfield, Samuel. Golden Hillock, Small Heath, Birmingham.
1861. ‡Whitford, J. Grecian-terrace, Harrington, Cumberland.
1852. ‡Whitla, Valentine. Beneden, Belfast.
Whitley, Rev. Charles Thomas, M.A., F.R.A.S., Reader in Natural Philosophy in the University of Durham. Bedlington, Morpeth.
1865. ‡Whittern, James Sibley. Wyken Colliery, Coventry.
1870. §Whittern, James Sibley. Walgrave, near Coventry.
1857. *Whitty, John Irwine, M.A., D.C.L., LL.D., C.E. 94 Baggot-street, Dublin.
1863. *Whitwell, Thomas. Thornaby Iron Works, Stockton-on-Tees.
*Whitworth, Sir Joseph, Bart., LL.D., D.C.L., F.R.S. The Firs, Manchester; and Stancliffe Hall, Derbyshire.
1870. §Whitworth, Rev. W. Allen, M.A. 185 Islington, Liverpool.
1865. ‡Wiggin, Henry. Metchley Grange, Harbourne, Birmingham.
1863. ‡*Wigham, John. Dublin.*
1854. §Wight, Robert, M.D., F.R.S., F.L.S. Grazeley Lodge, Reading.
1860. ‡Wilde, Henry. 2 St. Ann's-place, Manchester.
1852. ‡Wilde, Sir William Robert, M.D., M.R.I.A. 1 Merrion-square North, Dublin.
1855. ‡Wilkie, John. 46 George-square, Glasgow.
1857. ‡Wilkinson, George. Monkstown, Ireland.
1861. *Wilkinson, M. A. Eason-, M.D. Greenheys, Manchester.
1859. §Wilkinson, Robert. Lincoln Lodge, Totteridge, Hertfordshire.
1869. §Wilks, George Augustus Frederick, M.D. Stanbury, Torquay
*Willert, Paul Ferdinand. Booth-street, Manchester.
1859. ‡Willet, John, C.E. 35 Albyn-place, Aberdeen.
1870. §William, G. F. Copley Mount, Springfield, Liverpool.
*Williams, Caleb, M.D. 73 Micklegate, York.
Williams, Charles James B., M.D., F.R.S. 49 Upper Brook-street, Grosvenor-square, London, W.
1861. *Williams, Charles Theodore, M.A., M.B. 78 Park-street, London, W.
1864. *Williams, Frederick M., M.P., F.G.S. Goonvrea, Perranarworthal, Cornwall.
1861. *Williams, Harry Samuel. 49 Upper Brook-street, Grosvenor-square, London, W.
1857. ‡Williams, Rev. James. Llanfairinghornwy, Holyhead.
1870. §Williams, John. 5 New Cavendish-street, London, W.
Williams, Robert, M.A. Bridehead, Dorset.
1861. ‡*Williams, R. Price. 22 Ardwick Green, Manchester.*
1869. §Williams, Stephen. Stonyhurst College, Whalley, Blackburn.
Williams, Walter. St. Alban's House, Edgbaston, Birmingham.
1865. ‡*Williams, William M. The Celyn, Caergwele, near Wrexham.*
1850. *Williamson, Alexander William, Ph.D., F.R.S., F.C.S., Professor of Chemistry, and of Practical Chemistry, University College, London. 12 Fellows-road, Haverstock-hill, London, N.W.
1857. ‡Williamson, Benjamin. Trinity College, Dublin.
1863. ‡Williamson, John. South Shields.
*Williamson, Rev. William, B.D. Datchworth Rectory, Welwyn, Hertfordshire.
Williamson, W. C., Professor of Natural History in Owen's College, Manchester. Fallowfield, Manchester.
Willis, Rev. Robert, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge. 23 York-terrace, Regent's Park, London, N.W.; and 5 Park-terrace, Cambridge.
1865. *Willmott, Henry. Hatherley Lawn, Cheltenham.
1857. ‡Willock, Rev. W. N., D.D. Cleenish, Enniskillen, Ireland.
1859. *Wills, Alfred. 43 Queen's Gardens, Bayswater, London, W.

Year of Election.

1865. ‡Wills, Arthur W. Edgbaston, Birmingham.
Wills, W. R. Edgbaston, Birmingham.
1859. §Wilson, Alexander Stephen, C.E. North Kinmundy, Summerhill, by Aberdeen.
1850. ‡Wilson, Dr. Daniel. Toronto, Upper Canada.
1863. ‡Wilson, Frederic R. Alnwick, Northumberland.
1847. *Wilson, Frederick. 81A Newman-street, Oxford-street, London, W.
Wilson, George. 40 Ardwick-green, Manchester.
1863. ‡Wilson, George. Hawick.
1869. ‡Wilson, George. Knaphill, Woking, Surrey.
1861. ‡Wilson, George Daniel. 24 Ardwick Green, Manchester.
1855. ‡Wilson, Hugh. 75 Glassford-street, Glasgow.
1847. ‡Wilson, James Hewetson. The Grange, Worth, Sussex.
1857. ‡Wilson, James Moncrieff. 9 College Green, Dublin.
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